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ON THE PRESENCE OF GRAPHITE AND ITS BEARING ON THE MIGMATITIC ENVIRONMENTAL CONDITIONS OF THE DIORITIC GNEISSES («DIORITES»), BASIC FORMATION IVREA-VERBANO (ITALY) **

Riassunto — La presenza di grafite negli gneiss dioritici della Formazione Basica Ivrea-Verbano convalida l'ipotesi formulata recentemente sulla loro genesi (CAPEDRI [1971] e cioè che dette rocce si siano formate in ambiente migmatitico per fenomeni di scambio tra rocce basiche e paraderivati associati.

Abstract — Graphite, observed for the first time in the dioritic gneisses (the so called «diorites» in the magmatic interpretation) of the Ivrea-Verbano Formation, supports the idea that these rocks are derived by migmatitic processes between basic and sedimentary interlayered materials. Its surviving in the dioritic gneisses attests a low Po_2 of the migmatitic environment.

INTRODUCTION

The southwestern part of the Basic Formation Ivrea-Verbano, belonging to the so called Ivrea-Zone, Western Italian Alps, has been always regarded as a typical magmatic unmetamorphosed Complex, intruded into metasedimentary rocks and constituted mainly by mafic rocks (gabbros and norites) and subordinately by ultramafic (peridotites and pyroxenites) and intermediate (diorites) rocks.

Recent investigations, however, have pointed out the metamorphic character of all the Complex. In particular it has been shown that the Basic Formation underwent two different metamorphic

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events (CAPEDRI [1971]): the first one affected the whole Complex in the pyroxene granulite subfacies and the second superimposing one acted retrogressively and with decreasing intensity from W to E in hornblende granulite subfacies to high amphibolite facies.

In the light of this view the Basic Formation Ivrea-Verbano is considered to be composed by:

1) rocks metamorphosed in the granulite facies (granulites);

2) rocks, originally granulitic, retrometamorphosed in high amphibolite facies (gneisses and amphibolites).

1) The *granulites* are represented mainly by mafic and subordinately by ultramafic types (corresponding respectively to the mafic and ultramafic subdivision in the magmatic interpretation).

Acid granulites are not widespread, nevertheless they have been well recognized to be intimately associated as regular bands within the basic types (BERTOLANI et al. [1970]). They show variable mineralogical composition so that two distinct paragenetic types may be recognized:

a) quartz-perthitic/mesoperthitic feldspar-garnet, and

b) quartz-perthitic/mesoperthitic feldspar-hypersthene assemblages, which are intimately associated. The most important thing to be outlined is that the acid types at item *a* may contain both sillimanite and graphite and therefore they are to be regarded as rocks derived from sedimentary material. The acid granulites at item *b*, on the contrary, could be considered as metasomatic rocks (BERTOLANI [1968]) derived by matter exchange possibly between basic and sedimentary material under granulitic conditions.

2) The rocks belonging to high amphibolite facies constitute a narrow band on the Eastern side of the Complex. They are represented by scarce *amphibolites* (retrogressively derived from mafic granulites) and by *gneisses*: these gneisses may be distinguished into *dioritic gneisses* (corresponding to the «diorites» of the magmatic interpretation: ARTINI et al., [1900], and to the «metadiorites» in recent interpretation: CAPEDRI [1971]), and into *pelitic gneisses*, present in subordinate amounts.

The pelitic gneisses show variable mineralogical composition, however the most frequent mineralogical association (quartz-feldspar-biotite-garnet-sillimanite-cordierite-graphite) is considered to be typical in the transition between the granulite facies and the amphibolite facies (WYNNE-EDWARDS et al. [1963]). Acid granulites are sporadically found as lenses in the pelitic gneisses; they are probably remnants of more regular bands originally interlayered within the basic granulites, a situation that is actually observable where the Complex has not been affected by amphibolite facies transformation (BERTOLANI et al. [1970]). The pelitic gneisses may be thought to be retrogressively derived from these acid granulites on the basis of the general field association and of the general metamorphic evolution of the Complex. When compared to the paraderivatives in granulite facies (BERTOLANI et al. [1970]), they are seen to be strongly depleted in K-feldspar and enriched in biotite and cordierite; chemically they appear to be depleted in SiO_2 and K_2O, while they appear to be enriched in MgO, FeO and Fe_2O_3.

DIORITIC GNEISSES

The dioritic gneisses are constituted by: andesinic plagioclase, perthitic K-feldspar, quartz, biotite, garnet, green-blue hornblende (rare) and by *relic* orthopyroxene and clinopyroxene. Ore minerals are normal constituents and *graphite* may be present.

Mineralogically they are hybrid rocks as minerals typical both of mafic granulites (e.g. orthopyroxene, clinopyroxene, plagioclase with An% = 70, present as relic phases), and of the associated paraderivatives (e.g. K-feldspar, quartz, and less frequently, graphite) are normally present in the same sample. When compared with the mafic granulites, these gneisses are seen to be very rich in K-feldspar and locally in quartz, both metasomatic in texture, but it is interesting to remember that all variations between true granulites and true dioritic gneisses may ben seen.

It has been shown (CAPEDRI [1971]) that chemically they cannot be correlated to the associated basic rocks simply on the basis of magmatic differentiation, as they deviate sensibly from true magmatic trends. A genesis of these gneisses by metasomatic processes has therefore been recently proposed (CAPEDRI [1971]).

The metasomatic phenomena are thought to have happened during the two successive metamorphic events referred to before and mainly in high amphibolite facies and are thought to have affected an originally inhomogeneous complex constituted by alternating basic and sedimentary material. In fact, inside the dioritic gneisses remnants differing in mineralogy and/or structure are frequently recognized: they are constituted by mafic material exhibiting «frozen» granulitic assemblages (basic plagioclase, orthopyroxene, clinopyroxene), often retrogressed partially or completely to amphibolites (less calcic plagioclase, green-blue hornblende, biotite); or by sedimentary material which shows granulitic paragenesis (acid granulites) or, normally, high amphibolite paragenesis (pelitic gneisses).

The metasomatic processes acted by means of acid mobilizates formed reasonably by partial fusion of the sedimentary material in the high amphibolite facies (the classic facies for migmatites), which permeated and reacted with mafic granulites giving rise to the so called «diorites». In the light of this view, the actual pelitic gneisses could be regarded as restitic material of originally K-Si-rich paraderivatives depleted in their original mobile components and thereby indirectly enriched with Fe and Mg.

Significance of graphite

Graphite is not widespread in the dioritic gneisses, however it is quite abundant in some samples particularly at the Sacro Monte of Varallo Sesia (Vercelli). It is present as well-preserved lamellae, highly deformed, showing undulatory extinction, kinking, banding (fig. 1); highly deformed lamellae may be arranged in snow-ball nodules (fig. 2).

Graphite is abundant in the paraderivatives associated in the dioritic gneisses, while it is absent in the mafic granulites.

The presence of graphite in the dioritic gneisses supports the idea of their migmatitic origin as illustrated before. In the light of this view, graphite may be regarded as a relic phase originally belonging to sedimentary material partially fused.

The migmatitic environment was characterized by higher oxydizing conditions with respect to basic granulites and paraderivatives associated. In fact, the ratio Fe_2O_3/FeO, which rises with the oxydizing conditions prevailing in a metamorphic environment, equals 0.15 (mean value) in the paraderivatives, 0.20 in the associated basic granulites, 0.33 in the dioritic gneisses. This ratio, however, is highly variable in the dioritic gneisses, ranging between 0.00 and 0.63: this high variability may be regarded, at least in part,

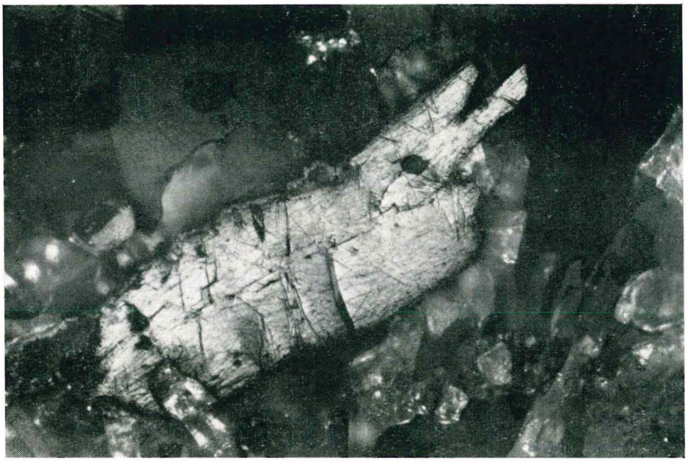

Fig. 1 - Lamella of graphite showing kinking. Crossed Nicols. 170X.

Fig. 2 - Lamellae of graphite arranged in snow-ball nodules Polarized light, 170X.

as a consequence of analytical errors inevitable when ferrous iron is determined in the presence of carbon. It is interesting to note that the lowest value of the ratio above has been characteristically found in a sample of dioritic gneiss (IV 150) containing graphite, which clearly reduced Fe''' to Fe'' during the analytical procedure. In fact, Fe_2O_3 must be present in this sample, as Fe_2O_3 has been determined in garnets (0.51%) and in biotites (7.56%) belonging to that sample.

Mg-Fe silicates of the dioritic gneisses show Fe_2O_3 contents different with respect to those determined in the same minerals belonging to the associated basic granulites: in particular hornblendes and biotites are enriched in Fe_2O_3, while garnets are depleted in the same oxide.

The oxygen pressure had however to be low.

It is well known that the oxygen pressure (Po_2) in the crust is clearly related to the molecular dissociation equilibrium of water; however, generally speaking, the acqueous fluids partecipating in metamorphic processes normally contain hydrogen in excess of pure water composition.

Moreover, the Po_2 is clearly related to the equilibrium with graphite, as graphite is unstable in oxydizing environments where it reacts with oxygen to give carbon dioxide lowering this way the original environmental Po_2.

In the present case two characters of the dioritic gneisses may be explained by thinking about a low Po_2 of the migmatitic fluids.

a) Presence of graphite in some dioritic gneisses.

It has been said that graphite is unstable in oxydizing conditions where it is to be expected to disappear completely, so more so when it is scarce as in the present case. Under such conditions graphite reacts with oxygen giving rise to CO_2; to this reaction may be attributed the relatively high Pco_2 that was realized in some dioritic gneisses where calcite may be seen to be intergrown with cogenethic biotite.

b) Presence of ilmenite, pyrrothite, pyrite as ore minerals.

Ilmenite, by far the most abundant ore mineral in the dioritic gneisses as well as in the basic granulites, is a stable phase in low oxygen pressure, while it tends to disappear along with rising oxygen pressure (CHINNER [1960]).

Pyrrothite and pyrite are undoubtedly unstable phases in oxydizing conditions. Hematite, that on the contrary is a stable phase in high oxydizing conditions, is present exceptionally in the dioritic gneisses and anyway it is absent in the graphite-bearing types.

Conclusions

The conclusion to be drawn is that the presence of graphite in the dioritic gneisses of the basic Formation Ivrea-Verbano gives new evidence on the metamorphic origin of these rocks, otherwise postulated in recent interpretation (Capedri [1971]). They may be interpreted as the result of migmatitic homogeneizing processes that involved basic granulites and metasedimentary interlayered material in high metamorphic conditions.

The environmental conditions were characterized by high P_{H_2O}, as it may be inferred by the presence of hydrated minerals (e.g. biotite, abundant; hornblende); on the contrary, P_{O_2} had to be sufficiently low to permit the existence of ilmenite, pyrrothite, pyrite as stable phases: this is generally the case for all the basic Formation Ivrea-Verbano, as these opaque minerals are present in all rock types.

Graphite is an unstable phase in oxydizing conditions: during the metasomatic homogeneizing processes which the dioritic gneisses are related to, graphite belonging to metasedimentary rocks is expected to have acted as reducing material by reacting with oxygen giving rise to carbon dioxide; its persistence in dioritic gneisses may be explained on the basis of low oxygen pressure of the migmatitic environment.

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References

Artini E., Melzi G. (1900) - Ricerche petrografiche e geologiche sulla Valsesia. *Mem. R. Ist. Lomb. Sci. Lett.*, **18**, 219-390.

Bertolani M. - (1968) - Fenomeni di trasformazione granulitica nella formazione basica Ivrea-Verbano (Alpi occidentali italiane). *SMPM*, **48/1**, 21-30.

BERTOLANI M., GARUTI G. (1970) - Aspetti petrografici della formazione basica Ivrea-Verbano in val Sessera (Vercelli). *Rend. Soc. Ital. Min. Petr.*, **26**, 433-474.

CAPEDRI S. (1968) - Sulle rocce basiche della formazione Ivrea-Verbano. 1. Considerazioni petrografiche e petrogenetiche sulla bassa Val Mastallone. *SMPM*, **48/1**, 103-112.

CAPEDRI S. (1971) - Sulle rocce della formazione basica Ivrea-Verbano. 2. Petrografia delle granuliti e rocce derivate affioranti nella Val Mastallone (Vercelli) e loro evoluzione petrogenetica. *Mem. Soc. Geol. It.*, **10**, 277-312.

CHINNER G. A. (1960) - Pelitic gneisses with varying ferrous/ferric ratio from Glen Clova, Angus, Scotland. *J. Petrology*, **1**, 178-217.

WYNNE-EDWARDS H. R. HAY P. W. (1963) - Coexisting cordierite and garnet in regionally metamorphosed rocks from the Westport area, Ontario. *Canad. Miner.*, **7**, 453-478.

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