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(SOUTH-WESTERN TAUERN WINDOW)

(with 13 figures, 9 tables and 1 geological map)

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(SOUTH-WESTERN TAUERN WINDOW)

In memory of our Teacher
Prof. ANGELO BIANCHI

CONTENTS

Key words: Pennine Basement, Late-Hercynian intrusives, Alpine metamorphism.

ABSTRACT

To better describe the geological phenomena related to the enclosed Map, the Authors decided to present the description of the geological and petrological peculiarities of the rocks appearing in this region in a single paper and to concentrate on the chemism and on the geological characteristics of orthogneisses.

In this area at least two Pennidic units may be recognized; the first, deeper one, formed by «Zentralgneiss» and by their Prevariscan cover on which, after a downcutting, the post-Hercynian transgressive Permo-Carboniferous and Triassic sequences were deposited; the second unit, which is clearly allochthonous, is formed by the well-known «Calcschists with ophiolites» complex (Calcschists thrust *auct.*). The orthoderivate, endowed with a pronounced foliation especially in the southern outcrop of the area, assume more and more massive textures in their northern shares along the ridge of boundary. Their more diffuse facies present a composition varying from granodioritic to quartzdioritic, even if there are acid and more basic differentiates from gabbrodioritic to gabbric.

Multiple dikes are present in this sector; main trends are subparallel to the widespread schistosity, but discordant bodies are also present sometimes with an anular direction.

The chemical composition of these orthoderivates is calcalcaline; the polyphasic peculiarity of these original plutonics is shown both by the dispositional relationships between the intrusive body and from the behaviour of some chemical elements.

Arkosic schistes and, less frequently, amphibolites, constituted the original covering of the Hercynic batholite; they often appear as a «lit par lit» injection or reduced to nebulitic products.

The distinction between metarcosic facies and orthoderivates, which is difficult to recognize in the field, has been corroborated by geochemical results.

Using a microprobe we have systematically analysed some minerals common in the ortho- and para-derivates (amphiboles, garnets and micas). The linear correlation, existing between some elements (Mg and Fe) present in these minerals and in the whole rocks, shows that these

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variations are correlated to compositional factors and that they do not have a clear metamorphic significance. For some other elements of the structural formulas of the amphiboles it is possible to state some thermobarometric conditions of the metamorphism. On the basis of these values and of some significant paragenesis, we can say that the temperatures of metamorphic balancing were close to 550° C and that the pressures were not above 6 Kb.

We have obtained slightly lower temperatures through the employment of the Calcite-Dolomite geothermometer applied to some marbles found in the southern zone.

RIASSUNTO

Nell'intento di meglio illustrare l'allegata Carta geologica, gli Autori hanno ritenuto di raccogliere in un'unica memoria la descrizione dei caratteri geologici e petrologici dei terreni affioranti in questa regione alpina, soffermandosi in particolare modo sul chimismo e sui caratteri mineralogico-petrografici degli ortogneiss.

Nell'area sono distinguibili almeno due Unità pennidiche; la prima, più profonda, costituita dagli «Gneiss Centrali» degli Alti Tauri e dalle loro coperture prevariside su cui, dopo una profonda erosione, si sono depositate le sequenze trasgressive permo-carbonifere e triassiche; la seconda, decisamente alloctona, rappresentata dal noto complesso dei Calcescisti con ofioliti (ricoprimento dei Calcescisti *auct.*).

Gli ortoderivati, dotati di una marcata scistosità negli affioramenti più meridionali dell'area, assumono tessiture sempre più massiccie nelle loro porzioni più settentrionali (cresta di confine). Le loro facies più diffuse hanno composizione da granodioritica a quarzodioritica pur non mancando differenziati acidi e più basici (gabbrodioritici fino a gabbrici).

Un'intensa attività filoniana interessa questo settore; sono più frequenti i corpi ad andamento subparallelo con la scistosità generale ma sono anche ben rappresentati quelli discordanti a volte con giacitura anulare.

Il chimismo di questi ortoderivati è calcalcalino; il carattere polifasico di queste originarie plutoniti è dimostrato dai rapporti giaciturali tra masse plutoniche e confermato dal comportamento di alcuni elementi chimici.

Scisti arcosici e più rare anfiboliti costituiscono lembi dell'originaria copertura del batolite ercinico; essi risultano spesso iniettati letto a letto o ridotti a prodotti nebulitici. La distinzione di queste facies metarcosiche dagli ortoderivati, che sul terreno avviene con una certa difficoltà, è stata convalidata dai risultati geochimici.

Su alcuni minerali comuni agli orto- e para-derivati (anfiboli, granati e miche) sono state effettuate analisi sistematiche alla microsonda. La correlazione lineare esistente tra alcuni elementi (Mg e Fe) presenti in detti minerali e nelle corrispondenti rocce fa ritenere che queste variazioni siano legate a fattori composizionali e non abbiano stretto significato metamorfico. Per alcuni altri elementi, nelle formule strutturali degli anfiboli, è possibile trarre indicazioni sulle condizioni termobarometriche del metamorfismo. Sulla base di questi valori e di alcune paragenesi significative si può ritenere che le temperature di equilibratura metamorfica fossero prossime a 550° C e che le pressioni non dovessero superare i 6 Kb.

Valori di temperatura leggermente inferiori (~ 500° C) sono stati ricavati utilizzando il geotermometro Cc-Dol applicato ad alcune facies dei calcescisti posti nel settore più meridionale dell'area.

ZUSAMMENFASSUNG

Mit der Absicht, die beigefügte geologische Karte besser zu erläutern, haben die Autoren es für vortilhaft gefunden, in einem einziger Bericht die Beschreibung der geologischen und petrologischen Merkmale der in diesem alpinen Gebiet auftrenden Gesteine zusammenzufassen, unter besonderer Berücksichtigung des Chemismus und der mineralogischen Beschaffenheit der Orthogneisse.

Im Untersuchungsgebiet sind wenigstens zwei pennische Einheiten unterscheidbar; die erste, tiefer gelegene, bestehend aus dem «Zentralgneis» und dessen vorvarizische Bedeckung, auf welche nach tiefgehender Erosion transgressiv Permo-Karbon- und Trias-Abfolgen abgelagert wurden; die zweite, eindeutig allocthone, bestehend aus dem bekannten Komplex von Bündnerschiefer (Kalkschieferdecke *auct.*).

Die in den südlichen Aufschüssen stark verschieferte Orthoderivate nehmen in nördlicher Richtung - im Bereich des Bergkammes an der Landesgrenze - massigeres Aussehen an. Die häufigste Fazies besitzt granodioritische bis quarzdioritische Zusammensetzung nebst basischeren Differenziaten von Gabbrodioriten bis Gabbros.

Eine starke Gangbildung kennzeichnet diese südlichere Region. Der Schieferung subparallele Gänge sind am häufigsten, daneben sind aber auch diskordante Gänge mit z.T. ringförmigen Verlauf vertreten.

Der Chemismus dieser Orthoderivate ist kalkalisch; der polyphase Charakter der ursprünglichen Plutonite wird aus Lagerungsverhältnissen zwischen plutonischen Einheiten sowie aus dem Verhalten einiger chemischen Elemente abgeleitet. Als überreste der ursprünglichen Bedeckung des herzynischen Batholits findet man heute Arkoseschiefer und seltener Amphibolite. Diese sind oft lagenweise injiziert worden oder liegen auch nur noch als nebulöse Reste vor. Die Unterscheidung der Metaarkosen von den Orthoderivaten - welche im Gelände etwas schwierig ist - wurde durch geochemische Untersuchungen bestätig. Einige gewöhnliche Minerale der Ortho- und Paragesteinsderivate (Amphibole, Granate und Glimmer) wurden systematisch an der Mikrosonde untersucht. Die lineare Korrelation einiger Elemente (Mg und Fe) in diesen Mineralen und in den entsprechenden Gesteinen lässt vermuten, dass diese Variation von der urssprünglichen Zusammensetzung und nicht von Metamorphose abhängen. Einige andere Elemente der Amphibole lassen Rückschlüsse auf die P-T Bedingungen der Metamorphose ziehen.

Aufgrund dieser Werte und bedeutender Paragenesen kann man annehmen, dass die metamorphen Gleichgewichtstemperaturen nahe 550° C waren und die Druke 6 Kb nicht überschritten haben. Etwas niedrigere T-Werte (ca. 500° C) ergab die Anwendung des Cc-Dol-Thermometers an einigen Marmoren und Kalkschiefern im südlichen Teil des Untersuchungsgebietes.

INTRODUCTION

The survey of Foglio 1 «Passo del Brennero» and 4a «Bressanone» (1969) of the Carta Geologica d'Italia allowed us to explore the high part of the Neves Valley (Selva dei Molini - Mülwald), where the inner pennidic units of the Tauern Window crop out. The peculiar tectonic complications, the abundance of dikes of different types in the granitoid rocks and the interesting geometric relationships of the gneissic bodies in the crystalline basement had already drawn our attention.

Only a few years later did we began the detailed field work, carried out on a 1/12.500 scale in the enclosed geological map.

GEOLOGICAL SETTING

In the tectonic window of the Hohe Tauern some pennine units crop out which have been correlated

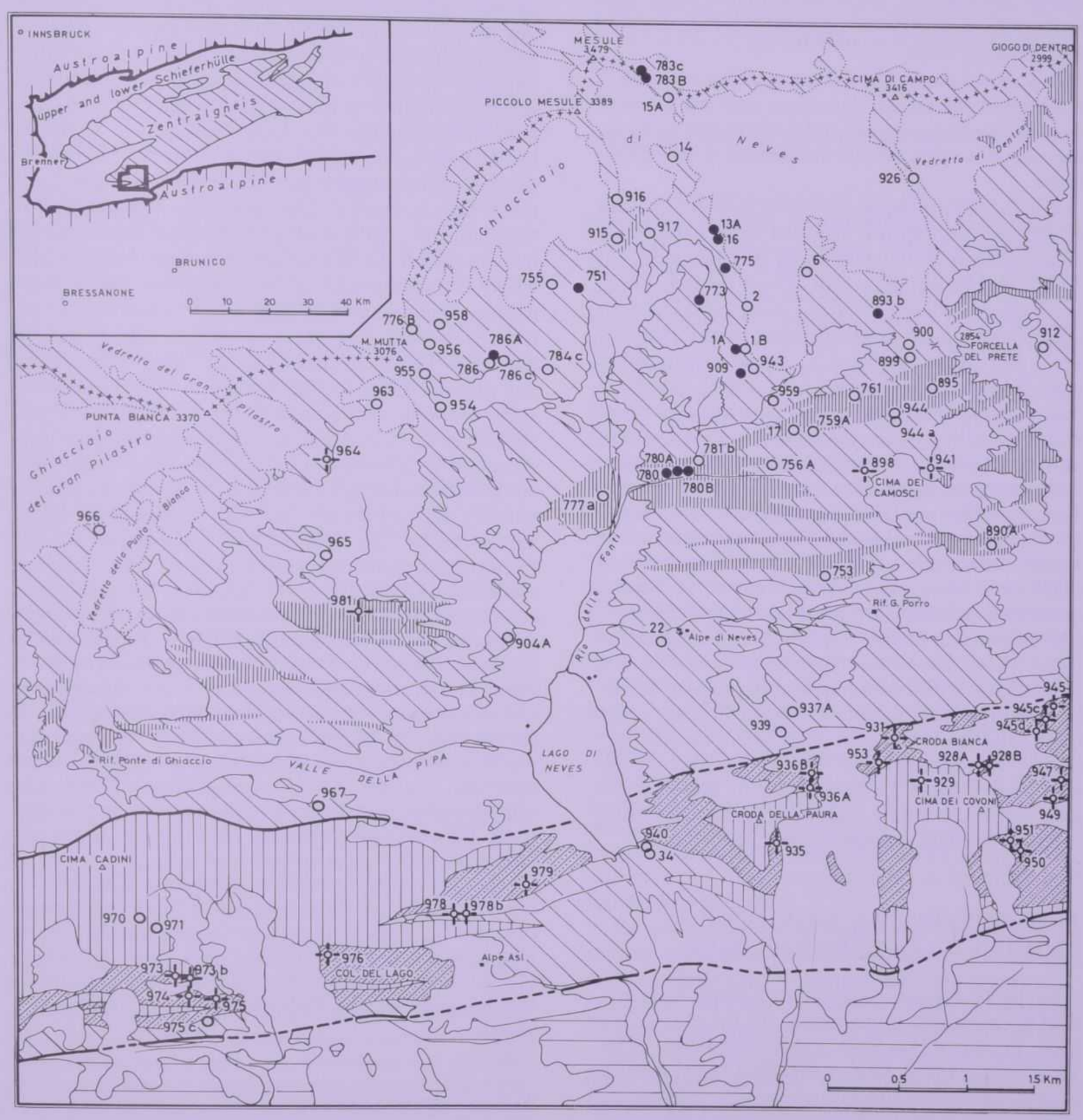


FIG. 1 - Geologic sketch of the Neves area with the location of the studied samples.

to the better exposed units of the Western Alps (TERMIER, 1912; DAL PIAZ, 1934). The area of the survey, which includes the metamorphic rocks identified by previous studies as «Gross Venediger Unit», «Greiner» and «Calcschists with ophiolites», is located to the South of the Punta Bianca (Weisszint) - Mesule (Gr. Möseler) - Cima di Campo (Turnerkamp) ridge which defines the border of the Austrian State.

Detailed geological maps of the area do not exist. However CHRISTA (1931) mapped in detail the Obere Zemmgrund area; MORTEANI (1971) and LAMMERER *et al.* (1976) published sketchmaps of neighbouring areas.

In a recent study, DE VECCHI and BAGGIO (1982) interpreted the Gross Venediger and the Greiner units as a single basement and cover nappe underlying the «Complex of the calcschists with ophiolites».

The former consist of prevalent granitoid bodies of various composition, intruded in an older basement («Untere Schieferhülle» by Austrian authors) during the Hercynian event. Deep erosion uncovered the embedding paleozoic complex («Habachserie») which must originally have been formed by acid and basic volcanics with interbedded psammitic-pelitic layers (STEYRER, 1983). Late Hercynian transgressive sequences consisting of basal graphitic pelites, conglomerates, sandstones and of an overlying carbonate series («Serie di Vizze», *auct.* - Hochstegen» p.p.) occur in some areas of the Tauern window, and they are correlable (DE VECCHI and BAGGIO, work cit.) to the «Wustkogel» and to the «Seindwinkel-serie» (Untere Schieferülle). All of these rocks were successively involved in Alpine orogenesis which caused complete recrystallization and rebalancing in the amphibolite to greenschist facies (SANDER's «Tauernkristallization»). In the «Calcschists with ophiolites» unit («Obere Schieferhülle») a basal series of Permo-Triassic rocks (Wustkogel-serie) has recently been found. Furthermore, in this area, the Post-Variscan transgressive cover (Upper Carboniferous to Mesozoic) is generally in continuity with its original substratum (Central Gneisse) or slightly detached from it.

THE PREVARISCAN BASEMENT AND THE GRANITOID GNEISSES

In the Tauern area gneissic rocks have been studied by many authors (SANDER, 1911, 1921, 1924 e 1929; BIANCHI e DAL PIAZ, 1934-1939; KARL, 1959-1964; EXNER, 1963). MORTEANI (1971) and LAMMERER *et al.* (1976) described the chemistry, genesis and relationships between the alpine metamorphic crystallization and the plutonic macro- and microstructures.

The Neves area is particularly affected by penetrative Alpine deformations or recrystallizations which strongly overprinted these granitoid complexes and their sedimentary covers. Obviously, the effects of the Alpine metamorphism make it difficult to draw conclusions about the original setting with the surrounding rocks. Nevertheless field observations allow us to recognize some significant features.

THE PREVARISCAN COVER

Some metamorphites from the pregranitic sequence, which are often injected «lit-par-lit», crop out in this region. They consist of banded metapelites alternated with amphibolic micascists (Tuxer Wacken by SANDER), granatiferous amphibolites, amphibole-epidote rich gneisses and micascists of Late-Paleozoic age; the latter are rich in variously linked leucocratic veins (ANGENHEISTER *et al.*, 1972). «Flaser-» and «Augen-gneisses» are associated with these paraderivates; such gneisses («B-gneise» of SANDER) have quite different textural and chemical features from the Hercynian metagranitoid bodies. Their chemical characters, together with their macro- and microstructure, make it possible to interpret them as original more or less mature arcosic material. These metasediments, injected by aplitic and granitic dikes, sometimes occur also in the inner areas of the massif, where they are hardly distinguishable from variously tectonized orthoderivates. Among the lithotypes of the Prevariscan basement some lenses of amphibolites with coarse almandine garnets and relicts of eclogitic paragenesis occur. These rocks are tectonically embedded in the Permo-Carboniferous cover. These mineralogical associations, testifying to peculiar metamorphic conditions, occur in the Prevariscan crystalline rocks cropping out in the Aurina Valley - Picco dei Tre Signori (Ahrntal - Drei Herren Spitz) area (DAL PIAZ, 1934); they are interpreted as evidence of an «Eoalpine event» in the Eastern Alps (MILLER, 1977; RAITH *et al.*, 1978); HOLLAND *et al.*, 1979; ENGLAND an HOLLAND, 1979; SELVERSTONE *et al.*; 1983). In our opinion, (*e.g.* DE VECCHI and BAGGIO, 1982), the metamorphic imprint is Prevariscan in age; in fact these HP relict assemblages are present only in the oldest sequences and, on the contrary, do not occur in the Mesozoic ophiolite complex. We believe, therefore, that Alpine metamorphism has caused only their reequilibration into amphibolic facies. More recently, by petrologic observations, DROP (1981) came to the same conclusion with regard to the eclogites of the Prevariscan cover of the Hochalm.

THE GRANITOID GNEISSES

Although the granitoid facies are the more widespread, types of different composition are present. The compositional variability of the original magmatics is, in itself, a distinctive feature of this

part of the Tauern area, a massif which, in its turn, shows greater compositional differences than the other Ercinic plutons in the Alps (D'AMICO, 1974). Furthermore, in the Mesule group (Grosser Mösele) dike systems of different composition are widespread and are substantially concordant with the schistosity, even though clearly discordant dikes occur. The relationships between the granitoid masses, make it possible to reconstruct a succession of magmatic phases which agrees with the one found by DAL PIAZ (1934) in the orthoschists of the Aurina Valley. Gabbric and dioritic masses, together with prevailingly acid dike swarms, precede the intrusion of granodiorites and large grained granites, which are followed by finer grained granodiorites. All of these rocks are injected by acid and basic dike systems and intrusive veins. In the Mesule area, plutonites with a syenitic composition and pegmatitic veins are lacking. Many authors have tried to explain the intrusion dynamics of these Hercynic granitoids suggesting different, often contrasting, patterns. Some of them, because of relationships with the surrounding migmatites, believe that these bodies represent deep intrusions (DAL PIAZ, 1934; CORNELIUS and CLARK, 1939; EXNER, 1963). On the basis of the kyanite pseudomorph after presumed sillimanite in the micaschist of the Eastern Tauern area and of contact metamorphism relicts in marbles of the Schlegeistal (FRANZ and AKERMAND, 1980; DROOP, 1981) believe that the granites have an epiplutonic nature and that many original contacts have disappeared owing to the effects of the regional Alpine metamorphism (HÖCH, 1969; MORTEANI, 1971; RAITH, 1971).

In the Neves area thermometamorphic parageneses do not exist and discordant contacts between metagranitoids and their original covers are rare. The relationships with the surrounding migmatites (amphibolic septa and paraderivates of various types which we observed in the field) show that the magmatic intrusion occurred fairly deeply within the crust previously affected by anatexis and by Variscan metamorphism.

The radiometric ages of the granitic gneisses raised some interesting problems which have partially conditioned the following stratigraphic-structural models. Before '50s, on the basis of geologic consideration, it had been inferred that the «Zentralgneise» were Westfalian in age. Whole rock datings by various authors (HAWKESWORT, 1976; CLIFF, 1981; JÄGER, 1973; SATIR, 1975; SATIR and MORTEANI, in press) range between 280 and 290 Ma or 210 and 240 Ma. Such values were obtained by indipendent isochrones and, therefore, are reliable. Also taking into account mistakes related to the time scale used, the former assign a Late Carboniferous age to the intrusion, the latter could indicate a Permo-Triassic age. Recently, CLIFF (1981) pointed out that, in massive samples from Granatspitzkern, the Rb/Sr total rock isocrone shows an age of 314 ± 32 Ma while in the contiguous, progressively more foliated gneisses the radiometric ages range between 265 ± 25 Ma and 219 ± 25 Ma. According to this author, these values have no cronological significance because the effects of the Alpine metamorphic recrystallisation might have modified the initial isotopic ratio. Owing to these uncertainties it may be right to attribute the Hohen Tauern with a Carboniferous age which is the one commonly ascribed to the main intrusive Variscan phase; this chronological classification agrees with the geological observations. Consequently, as asserted by some researches and in accordance with the age of the other Ercynic massifs in the Alps, it is becoming more and more plausible to date them as Carboniferous.

THE POST-VARISCAN COVER

After the denudation of the Hercynian chain, a transgressive sequence was deposited, consisting of original carbonaceous pelites heteropic with sandstones and conglomerates with granitic pebbles; such a sequence shows strong variations in thickness, typical of the pennidic Permo-Trias deposits. In the western part of the Vizze Valley, DE VECCHI and BAGGIO (1982) recognized two different stratigraphic sequences; the first one recognizable in the Vizze-Vallaccia area and the latter at Spina del Lupo. Throughout the south-western part of the Tauern window the Neves sequence is most similar to the Vizze-Vallaccia one. Here the graphitic garnet micaschists and the black graphitic cloritoid quartzites can be considered the oldest term. They crop out in the south-western part of the map, between Cima Ponte di Ghiaccio (Eisbrückspitze) and Cima della Pipa (Pfeifenspitze), and are Upper Carboniferous in age (DAL PIAZ, 1934; DE VECCHI and BAGGIO, work cit.). Arcosic sandstones and conglomeratic gneisses containing rounded aplitic and rarely small-grain granitic pebbles overlie and/or laterally replace the graphitic schists. These rocks have undergone a strong penetrative deformation; their «pebbles», being stretched according to the lineation, make the rocks similar to «Augen-» or «Flaser-» gneisses. In this area, as in the Vizze Valley, alternating arcosic metaconglomerates, micaschists and black quartizes also crop out. These sequences are to be considered Carboniferous in age.

By gradual or sharp transition, Permo-Scytian marine whitish or yellowish quartzites follow upwards underlying a sequence consisting of gray granoblastic marbles, yellowish dolomitic marbles (bearing rare levels of white micas, phlogopite and quartz), and light coloured fetid large grained marbles. Vuggy dolomitic marbles have never been found. The carbonatic sequence here described, which has probably a Triassic to Jurassic age, is fairly well correlatable to the «Spina del Lupo» (Wolfendorn) one in the Vizze Valley, and seems to correspond partially to the sequence «Tux marbles» - «Hochstegen Marbles» (*auct.*).

THE CALCSCHISTS WITH OPHIOLITES (Obere Schieferhülle-Glockner Decke *auct.*).

This allochthonous unit, which crops out in the southern part of the geologic map, is composed of rocks of prevailing carbonatic composition.

Recently in the Vizze Valley some Permo-Triassic basal sequences have been pointed out by DE VECCHI and BAGGIO (1982). Similar rocks also have been found in the Neves area and, by analogy, they have been attributed the same significance. They consist of grey-greenish fine grained arenaceous gneisses, which are gradually replaced upwards by prevailing grey impure quartzites with calcareous cement alternated with micaschists.

Micaceous white-yellowish sometimes dolomitic marbles follow («Dolomia di Vizze» *auct.*). These basal metamorphites crop out only in lenses or «boudines» along the tectonic limit between this unit and the underlying one. The carbonate sequence, which is the most characteristic part of the «Calcschists with ophiolites», has already been fully described in other works by BAGGIO (1969) and DE VECCHI and PICCIRILLO (1968). Therefore only its general features are here summarized.

Two calcschist complexes separated by a metaophiolitic interval can be outlined.

The lower one is mainly characterized by carbonate facies, consisting of prevailing bluish and grey marbles intercalated by rare quartzites and phyllitic micaschists. The metaophiolitic interval follows in an upward direction, consisting of albite-oligoclase amphibolite, serpentinites and more rarely *ovarditi,* always associated with coloured banded sometimes dolomitic marbles.

The latter is a typical key-bed, always located at the base of the metaophiolitic complex. The transition from the latter to the upper part of the «Calcschists with ophiolites» is generally marked by epidote bearing rocks (*epidositi*) rarely intercalated with thin levels of manganiferous quartzites and «silver» porphyroblastic albite micaschists. The anomalous Cu and Zn enrichment in these lithofacies may be caused by sinsedimentary volcanic gases on volcano-sedimentary materials. The upper complex of the unit is composed of an original more or less rich in carbonate matrix arenaceous-pelitic sequence referred by DE VECCHI and BAGGIO (1982) to a flysch-like series. This sequence consists of prevalent impure mica rich marbles, sometimes garnetiferous grey-brown carbonate quartzites, graphite phyllite garnet bearing micaschists and subordinates banded dolomitic marbles often associated with chlorite schists and quartzites. All of these rocks are rare in the Neves area and it was impossible to distinguish them in the geological map.

LAMMERER *et al.* (1981) have interpreted the upper complex as a unit tectonically detached from the lower one through a contact emphasized by lenses and shingles of serpentinites and of marbles. In our opinion such a setting may be only local due to anomalous contacts in some places of the Tauern window. Furthermore such a situation cannot be generalized because in many places of the region the continuity of the two calcschist complexes is incontestable. On the basis of its geochemical characters LAMMERER *et al.* (1981) believe that the flysch-like complex consists of distal turbidites deposited in an abyssal environment under C.C.D. FRISCH (1980) is also of the opinion that these rocks derive from a flyschioid sequence.

In the flysch-like complex throughout the southwestern part of the Tauern Window, more or less continuous layers of dolomitic marbles alternate with calcschists and carbonates bearing quartzites. In our opinion these alternating rocks and their lateral continuity are hardly referable to shingles or relics of olistolites, tectonically comprised in the sequence. Furthermore, even if dolomite can in fact form at a depth greater than 1500 m (KELTS and MAC KENZIE, 1984) the general paleogeographic setting does not agree with the abyssal sedimentary environment suggested by the above mentioned authors.

TECTONIC SETTING

The Neves region lies in the south-western part of the Tauern window, which is a tectonic structure due to an important culmination of the Alpine nappe pile.

The Tux massif to the North, and the Aurine Alps to the South constitute two important subordinate structures. Their metamorphic covers, therefore, form two large anticlines separated by the Vizze Valley syncline.

The original setting of the rocks is often masked by a widespread E-W foliation and by a more or less vertical dip caused by the Alpine metamorphic events. Furthermore, the slip surfaces of the Alpine main phases have been strongly blastized by regional metamorphism. As happens all over the Tauern window, also in the Neves area two different pennidic units are distinguishable. The deeper unit corresponds to the «Tux - Aurine Alps complexes» and to their parautochthonous covers («Greiner serie», «Habach serie», «Vizze serie», «Hochstegen» *auct.*); it is characterized by gently folded structures and large wedgings chiefly in the neighbourhood of the tectonic contact with the overlaying «Calcschists with ophiolites» complex. This complex, which is allochthonous and overthrusts the former, is plastically deformed: in the Northern part of the Tauern window (Vizze Valley) the folds are Northward verging, while in the Southern part they are progressively overturned towards the South (BAGGIO, 1969). In this area the Permo-Carboniferous and the Mesozoic covers of the orthogneisses are clearly sheared. The still recognizable folds often show

mostly recrystallized shear zones, which suppress lithologic terms and originate tectonic wedges (DAL PIAZ, 1934). Because of the impossibility of mapping all of them, only the main shear surfaces are drawn in our geological map.

The tectonic setting is even more complicated owing to the presence of late brittle-type tectonics, which variously cut the main structures. The most important faults are subvertical, ENE-WSW, they generally separate crystalline complexes characterized by different lithologic features. They are parallel to the «Croda Rossa Line» (already pointed out by DE VECCHI and BAGGIO, 1982) in the Vizze area. The tectonic structures are partially masked by Alpine crystalloblastic textures sometimes tectonically deformed; this testifies to a long and complicated history. The amount of the throw is about one hundred meters. The N 70° E fault crossing the Forcella del Prete (Pfaffenscharte) is worth mentioning, to the West, at Rio delle Fonti it joins another E-W fault which extends from the Vedretta della Punta Bianca to the Passo di Neves. These two faults separate prevailing amphibolite facies from granitoid types which crop out to the North and the South. Such a sharp break in the lithologic sequence is probably due to a considerable throw. The tectonic discontinuity, extending in the southern part from Cima della Pipa to the Croda della Paura - Croda Bianca area, through the Neves Lake, shows a similar trend. It separates the above mentioned metagranitoids from the Paleo-Mesozoic covers. In this area the tectonic contact between the «Calcschists with ophiolites» and the underlying pennidic unit, also has a more or less E-W direction; its attitude is subvertical or locally slightly overturned towards the South, so that it may be considered an effect of isostatic arrangement after the main orogenetic compression. The last system of fractures has a N 20°-30° E direction and subvertical attitude. This is a group of subordinate transcurrent lines whose continuity is not always recognizable and which has shows little heave. Perhaps they are the latest ones and probably they were reactivated during recent times.

GNEISSIC ROCKS

In their geologic-petrographic study BIANCHI and DAL PIAZ (1934) described in detail two groups of metamorphic rocks (ortho- and metaschists) which on the whole constitute the deeper pennidic unit cropping out in the Tauern window. According to these authors the metaschists, interpreted as Hercynic migmatites, are the oldest terms of the sequence (perhaps Prepaleozoic). Alpine metamorphism trasformed the granitic masses and the country injected paragneisses into the so called «Central Gneisses» associated with ancient schists in which it is still possible to find some primary features (phantoms of folds). This setting has been confirmed by many field investigations carried out all over the South-Western part of the tectonic window.

The Alpine metamorphism gneissificated the intrusive rocks and the connected tectonics, masked and often obliterated the contacts with the metamorphosed country rocks.

The Mesule orthogneisses become less and less foliated from the South, near the contact with the calcschists, to the North along the boundary ridge. However microscope observations confirm that the massive coarse grained granitoid rocks also have a gneissic fabric and that the original mineral association has been generally reequilibrated by the Alpine metamorphism.

As it is visible in our geological map, in the outlying areas to the South of an immaginary line joining the Rifugio Porro saddle (Chemitze Hütte Scharte) and the Ponte di Ghiaccio (Eisbrücke Hütte), the schistosity becomes more and more marked and the gneisses are slightly more basic in composition. Paraamphibolites are frequently associated and have been interpreted by LAMMERER *et al.* (1976) as volcanics.

THE PETROGRAPHIC FACIES OF THE METAPLUTONITES (1)

On the basis of petrological observations and geochemical features the following groups may be distinguished: granitic gneisses, granodioritic gneisses, dioritic and gabbric gneisses.

GRANITIC GNEISSES

These rocks show both massive and markedly foliated structures, with a more or less evident lineation. In the field, the transition between the typologies is often continuous but sometimes there is a sharp contact, especially where structural discontinuites exist. Due to the thermodinamic reorganization of the magmatic rock, the textural variations are associated with more or less evident phenomena of metamorphic segregation. The «Augen-» and «Flaser-gneisses» are rarely formed by porphyroblasts but, are generally constituted by a more or less abundant quartz granoblastic fabric to which alkalifeldspars are often associated. The mineral association of the granitic gneisses is fundamentally the same as the original magmatics.

Quartz, K-feldspar mostly microcline, plagioclase with cores dotted by metamorphic segretation pro-

(1) The microstructural characters and the metamorphic facies of the «Gran Veneziano» orthoderivates, have been described by BIANCHI and DAL PIAZ (1934). Through detailed geologic-petrographic studies the authors demonstrated the Hercynic age of the granitic body and described the transformations which these rocks underwent during the Alpine metamorphic cycle. They gave a modern application to some concepts of petrotectonics which SANDER had been developing.

ducts and micas are the typical minerals. Allanitic epidote, zircon and apatite are the commonest accessories.

Expecially in the massive facies less influenced by the dynamic effects, the metamorphic recrystallization still allows us to recognize substantially well preserved magmatic structures. The plagioclase crystalloblast, whose primary zoning is still recognizable through distribution and thickening of the clinozoisite and sericite inclusions, have an albitic composition (5-6 % An). At the contact with plagioclase, K-feldspar often shows myrmekitic microimplication structures and at the nucleus sometimes large zones have micropertitic strings.

White mica, which is normally subordinated in the massive facies, is more abundant and becomes markedly lepidoblastic in the more foliated facies where it concentrates in the schistosity planes and shows more or less evident decussate structures. The growth and the greater quantity of these phyllosilicates in the foliated facies is essentially due to metamorphic segregation during the synkinematic phase. In any case biotite shows a dark brownish absorption pattern and a chemical composition of Fe-biotites (see anal. Tab. 6).

In the matrix almandine, with essentially idioblastic or sometimes poikiloblastic, «atoll like» textures, is often present.

Gneisses with leucoquartzdioritic and granodioritic composition

They constitute the most frequent rocks and occur both in massive and in markedly foliated facies; in the latter case, «eyes» and «lenses» may be formed, mostly composed of a mosaic of equidimensional quartz grains, sometimes of «tape like» shaped quartz and, more rarely, of sodic plagioclase.

Moreover, all these facies are particularly rich in «Schlieren», locally still distinguishable as elements of the country rocks or as magmatic authigenic concentrations. Their often lengthened shape agrees with the general trend of the foliation, even if there are clear examples of sharp unconformities. This rock group is distinguishable from the granitic gneisses due to their coarser grain size and the greater abundance of melanocratic minerals.

In the most femic types, biotite substitues and inherits the mostly prismatic form of the amphibolic host. The plagioclase shows a slight normal zoning shading from core to rims with a narrow range of An contents (16-5% An). Sometimes, phantoms of the original rhythmic and reverse zoning marked by a more or less intense segregation of small epidotic crystal can be observed. The K-feldspar, often microcline, is influenced by a more or less intense microperthite exolution and by microimplications with the plagioclase.

Fine-grained idioblastic clinozoisite-pistacite and almandine are minerals with a well defined metamorphic genesis, while allanite is a magmatic relict.

In the foliated rocks, white mica is generally characterized by decussate structures and constitutes swarms; in the massive rocks this mineral is normally absent.

The coloured mica belongs to the Fe-biotite group with a pleocroism varying from dark brownish to light yellow (see Tab. 6). Zircon, apatite and opaque minerals are common accessory minerals and occasionally calcite granoblasts are also present.

Dioritic gneisses

Foliated more or less eye-structured facies are frequent, while types with well preserved magmatic fabric are rare. Plagioclase is the most abundant mineral; it develops as porphyroblasts and shows marked poikiloblastic textures. In the rocks where the intrusive fabric is better preserved, the thick clinozoisite segregation, which characterizes the core of the plagioclases, indicates the primary Ca-feldspar composition. The metamorphic plagioclase associated with these epidotic segregations shows evident shaded zoning. Mostly, the core has an oligoclasic composition (20-25% An), while the rim is albitic. This seems to confirm that the zoning of the plagioclase is strictly related to the composition of the magmatic feldspar. In fact in a thermometamorphic environment poor in fluids the transformation:

$$\text{Anorthite} + H_2O \rightarrow \text{Oligoclase} + \text{Zoisite}$$

hardly occurs.

Fine-grained ore inclusions are common in horneblende crystals, and they are arranged along two sets of well defined trails crossing each other at angle an of 56°. Such geometrical feature indicates that the horneblende crystals nucleated and grew replacing old, differently oriented amphibole crystals. Metamorphic amphibole, which often appears to have been recrystallized at the expence of that of magmatic origin, certainly had a higher iron and titanium oxides contents.

Biotite shows a typical pleocroism varying from yellow-red to light yellow-green, and it never shows the dark brownish colours typical of the Fe-biotites. Chemical analyses (see Tab. 6) confirm that they mostly belong to the Mg-biotite group.

Quartz and K-feldspar also occur as fine-grained granoblastic accessory minerals.

Epidote sometimes has a pistacitic core; almandine-grossularite garnets (see Tab. 8) are common; sphene and ore minerals are accessory components.

TABLE 1a - Chemical compositions, Niggli- and De La Roche values of orthogneisses

Samples	Granite Gneisses BRS 915	BRS 755	BRS 966	BRS 939	$\bar{x}$ (4)	σ	Leucoquartzdiorite and Trondhyemite Gneisses BRS 965	BRS 916	BRS 759 A	BRS 958	BRS 15 A	BRS 959	BRS 6	BRS 937 A	BRS 944 A
SiO_2	75,35	74,11	73,29	72,00	73,69	1,40	73,50	72,13	71,52	70,97	70,72	70,53	70,50	70,48	70,47
TiO_2	0,27	0,25	0,15	0,27	0,23	0,06	0,31	0,28	0,26	0,45	0,42	0,39	0,34	0,29	0,43
Al_2O_3	13,29	14,09	13,72	14,28	13,84	0,44	13,62	14,64	14,40	15,05	14,82	15,61	15,27	15,13	14,98
Fe_2O_3	0,35	0,22	0,55	0,76	0,47	0,23	1,49	0,41	1,07	0,72	0,46	0,65	0,35	0,68	0,50
FeO	1,72	1,52	1,12	1,86	1,56	0,32	1,43	1,86	1,75	1,95	2,53	2,26	2,55	1,88	2,43
MnO	0,05	0,06	0,05	0,06	0,06	—	0,07	0,04	0,05	0,06	0,05	0,06	0,03	0,08	0,06
MgO	0,29	0,28	0,34	0,62	0,38	0,16	0,67	0,42	0,60	0,57	0,70	0,65	0,66	0,85	0,63
CaO	1,42	1,65	1,20	1,65	1,48	0,21	2,08	2,72	2,38	3,01	2,71	2,91	3,09	1,29	2,80
Na_2O	3,69	3,87	4,03	4,38	3,99	0,30	3,64	4,64	4,30	4,20	4,25	4,46	4,39	4,42	4,00
K_2O	3,10	3,55	3,90	2,76	3,33	0,50	2,00	1,91	2,45	1,90	2,50	1,81	1,86	3,35	2,18
P_2O_5	0,07	0,07	0,06	0,09	0,07		0,12	0,08	0,10	0,11	0,12	0,13	0,08	0,10	0,14
H_2O^+	0,44	0,36	1,36	0,79			1,07	0,39	0,66	0,84	0,53	0,66	0,62	0,95	0,98
H_2O^-	0,05	0,03	0,04	—			0,02	0,12	0,09	0,02	0,12	—	—	0,12	—
	100,09	100,06	99,81	99,52			100,02	99,64	99,63	99,85	99,93	100,12	99,74	99,62	99,60
	(p.p.m)														
Sr	180	n.d.	145	n.d.			270	n.d.	251	296	257	n.d.	271	n.d.	n.d.
Rb	90	n.d.	108	n.d.			64	n.d.	69	64	73	n.d.	70	n.d.	n.d.
Zr	145	n.d.	106	n.d.			148	n.d.	137	145	163	n.d.	152	n.d.	n.d.
Y	6	n.d.	8	n.d.			8	n.d.	2	4	4	n.d.	2	n.d.	n.d.
Rb/Sr	0,321	n.d.	0,744	n.d.			0,237	n.d.	0,275	0,216	0,284	n.d.	0,258	n.d.	n.d.
K/Rb	285	n.d.	300	n.d.			259	n.d.	294	246	284	n.d.	216	n.d.	n.d.
	Niggli														
si	441	412	415	373			399	365	358	347	338	333	334	350	344
al	45,8	46,2	45,8	43,6			43,5	43,6	42,5	43,4	41,8	43,4	42,5	44,3	43,1
fm	12,7	10,6	10,8	16,1			18,3	12,8	16,0	15,0	17,0	16,0	16,1	17,0	16,6
c	8,9	9,8	7,3	9,2			12,1	14,7	12,8	15,8	13,9	14,7	15,6	6,9	14,6
alk	32,5	33,4	36,2	31,1			26,1	28,9	28,7	25,8	27,3	25,8	25,7	31,9	25,7
k	0,35	0,38	0,39	0,39			0,26	0,21	0,27	0,23	0,27	0,21	0,23	0,32	0,26
mg	0,20	0,22	0,27	0,30			0,30	0,25	0,28	0,28	0,29	0,28	0,28	0,37	0,28
al-alk	13,3	12,7	9,6	12,5			17,4	14,7	13,8	17,6	16,2	17,6	17,0	12,4	14,4
	De La Roche														
R_1	2922	2680	2492	2527			3055	2643	2586	2711	2526	2604	2615	2268	2675
R_2	427	466	414	484			523	599	566	646	615	650	663	477	624
S.I. (*)	3,2	3,0	3,4	6,0			7,4	4,6	6,0	6,1	6,7	6,7	6,8	7,7	6,5

(*) = MgO x 100 / MgO + Fe_2O_3 + FeO + Na_2O + K_2O
Abbreviation: BRS = SHEET BRESSANONE

TABLE 1b - *(continued)*

Samples	Leucoquartzdiorite and Trondhyemite Gneisses BRS 899	BRS 926	BRS 967	BRS 2	BRS 900	x̄ (14)	σ	Granodiorite Gneisses BRS 963	BRS 781 b	BRS 944	BRS 14	BRS 943	BRS 954	x̄ (6)	σ
SiO_2	70,03	69,35	69,12	69,11	68,86	70,52	1,27	68,49	68,30	67,99	66,49	66,35	66,06	67,28	1,09
TiO_2	0,48	0,30	0,31	0,37	0,55	0,37	0,09	0,50	0,57	0,54	0,48	0,68	0,58	0,56	0,07
Al_2O_3	15,17	15,47	15,93	15,82	15,59	15,11	0,61	15,17	15,67	16,03	16,17	16,32	16,84	16,03	0,57
Fe_2O_3	0,29	0,48	0,47	0,63	0,11	0,59	0,14	0,59	0,65	1,14	0,85	0,74	1,19	0,86	0,25
FeO	2,59	2,42	2,38	2,60	2,50	2,22	0,38	3,45	3,20	2,69	3,26	3,66	2,70	3,16	0,39
MnO	0,09	0,06	0,05	0,03	0,06	0,06	—	0,05	0,09	0,08	0,09	0,11	0,09	0,09	—
MgO	0,67	0,64	0,71	0,74	0,80	0,66	0,16	1,37	0,93	0,90	1,14	1,08	0,88	1,05	0,20
CaO	2,48	2,50	2,45	3,63	2,31	2,59	0,54	3,96	3,46	3,19	2,59	3,92	3,90	3,50	0,54
Na_2O	3,85	4,63	4,61	4,31	3,68	4,24	0,45	3,45	3,95	3,85	5,02	4,23	4,44	4,16	0,54
K_2O	3,42	3,10	2,76	1,65	4,26	2,51	0,80	1,80	2,01	2,55	2,35	1,86	1,85	2,07	0,31
P_2O_5	0,15	0,11	0,11	0,11	0,24	0,12		0,14	0,18	0,07	0,17	0,19	0,14	0,15	
H_2O^+	0,67	0,45	0,80	0,64	0,74			0,91	0,86	0,98	0,86	0,79	0,96		
H_2O^-	0,03	0,09	0,06	0,03	0,01			0,03	0,01	0,03	0,13	0,06	0,03		
	99,92	99,60	99,76	99,67	99,71			99,91	99,88	100,04	99,60	99,99	99,66		
	(p.p.m)					x̄ (7)								x̄ (4)	
Sr	n.d.	213	245	n.d.	n.d.	258		258	301	n.d.	220	317	n.d.	273	
Rb	n.d.	95	79	n.d.	n.d.	73		66	58	n.d.	71	54	n.d.	62	
Zr	n.d.	152	141	n.d.	n.d.	148		114	182	n.d.	207	225	n.d.	182	
Y	n.d.	6	5	n.d.	n.d.	4		4	5	n.d.	4	9	n.d.	6	
Rb/Sr	n.d.	0,446	0,322	n.d.	n.d.			0,256	0,195	n.d.	0,323	0,170	n.d.		
K/Rb	n.d.	271	290	n.d.	n.d.			226	288	n.d.	275	286	n.d.		
	Niggli														
si	334	320	319	311	322			297	301	299	279	272	274		
al	42,6	42,1	43,3	42,0	43,0			38,7	40,7	41,5	40,0	39,4	41,1		
fm	16,5	15,7	15,9	17,0	16,0			23,4	20,4	19,9	21,6	21,8	18,8		
c	12,7	12,4	12,1	17,5	11,6			18,4	16,3	15,0	11,7	17,2	17,3		
alk	28,2	29,9	28,7	23,5	29,4			19,5	22,5	23,6	26,7	21,6	22,7		
k	0,37	0,30	0,28	0,20	0,43			0,25	0,25	0,30	0,23	0,22	0,21		
mg	0,29	0,28	0,31	0,29	0,35			0,38	0,30	0,30	0,33	0,30	0,29		
al-alk	14,4	12,2	14,6	18,5	13,6			19,2	18,2	17,9	13,3	17,8	18,4		
	De La Roche														
R_1	2408	2166	2238	2592	2199			2795	2559	2452	1976	2348	2275		
R_2	596	603	609	735	592			789	723	700	651	793	791		
S.I.	6,2	5,7	6,5	7,5	7,1			12,9	8,7	8,1	9,1	9,4	9,1		

TABLE 1c - (*continued*)

	Tonalite Gneisses												
Samples	BRS 786	BRS 955	BRS 784 c	BRS 34	BRS 956	BRS 940	BRS 22	BRS 971	BRS 970	BRS 904 A	BRS 917	$\bar{x}$ (11)	σ
SiO_2	65,86	65,52	65,51	65,46	65,20	65,20	65,11	64,59	63,38	63,76	62,91	64,68	0,95
TiO_2	0,57	0,65	0,60	0,52	0,61	0,63	0,45	0,66	0,71	0,67	0,71	0,62	0,08
Al_2O_3	16,55	16,88	17,25	16,69	16,98	16,68	16,69	15,58	15,97	16,55	17,47	16,66	0,53
Fe_2O_3	1,11	0,96	0,76	0,88	0,15	1,02	0,71	1,38	1,32	1,18	0,74	0,93	0,34
FeO	3,54	3,16	4,11	3,46	3,51	3,52	3,59	3,65	3,89	4,34	4,21	3,73	0,36
MnO	0,06	0,11	0,06	0,08	0,09	0,11	0,08	0,09	0,09	0,09	0,12	0,09	—
MgO	0,86	0,90	0,90	1,20	1,12	1,08	1,12	2,02	2,13	1,44	1,11	1,26	0,43
CaO	4,28	4,13	4,06	3,99	3,91	3,83	3,99	4,20	3,98	4,04	4,50	4,08	0,19
Na_2O	4,30	4,30	4,51	4,51	4,48	4,37	4,67	3,11	3,34	4,67	4,50	4,25	0,52
K_2O	1,75	1,74	2,14	2,16	2,18	1,98	1,94	2,75	2,71	1,88	2,12	2,12	0,34
P_2O_5	0,16	0,17	0,19	0,17	0,19	0,20	0,19	0,18	0,20	0,26	0,21	0,19	
H_2O^+	0,82	0,96	0,77	0,85	1,16	1,09	0,97	1,25	1,81	1,00	0,82		
H_2O^-	0,04	0,06	0,10	0,05	0,03	0,01	0,04	0,06	0,03	0,05	0,05		
	99,90	99,54	100,96	100,02	99,61	99,72	99,55	99,52	99,56	99,93	99,47		
	(p.p.m)											$\bar{x}$ (7)	
Sr	323	n.d.	298	335	n.d.	n.d.	320	218	238	263	n.d.	285	
Rb	52	n.d.	67	61	n.d.	n.d.	50	86	84	50	n.d.	64	
Zr	259	n.d.	279	250	n.d.	n.d.	208	119	132	276	n.d.	218	
Y	9	n.d.	2	—	n.d.	n.d.	4	10	12	10	n.d.	7	
Rb/Sr	0,161	n.d.	0,156	0,182	n.d.	n.d.	0,156	0,394	0,353	0,190	n.d.		
K/Rb	279	n.d.	265	294	n.d.	n.d.	322	265	268	312	n.d.		
	Niggli												
si	266	268	255	259	264	262	259	252	243	240	236		
al	39,4	40,7	39,6	38,9	40,5	39,6	39,1	35,8	36,0	36,7	38,6		
fm	20,7	19,6	21,1	21,4	19,4	21,8	21,0	28,0	28,7	25,4	21,9		
c	18,5	18,1	17,0	16,9	16,9	16,5	17,0	17,6	16,3	16,3	18,1		
alc	21,3	21,6	22,4	22,7	23,2	22,1	22,9	18,6	19,0	21,6	21,4		
k	0,21	0,22	0,40	0,24	0,24	0,30	0,21	0,36	0,34	0,21	0,24		
mg	0,25	0,28	0,25	0,33	0,35	0,30	0,32	0,42	0,42	0,32	0,28		
al-mg	18,1	19,1	17,2	16,2	17,3	17,5	16,2	17,2	17,0	15,1	17,2		
	De La Roche												
R_1	2314	2305	2116	2125	2127	2192	2099	2406	2247	1986	1945		
R_2	825	818	817	814	807	790	810	855	845	828	879		
S.I.	7,5	8,1	7,3	9,9	9,8	9,0	9,4	15,8	16,1	10,2	8,8		

TABLE 1d - *(continued)*

Samples	Diorite Gneisses BRS 912	BRS 786 c	BRS 895	BRS 761	x̄ (4)	Gabbrodiorite and Gabbro Gneisses BRS 17	BRS 776 B	BRS 890 A	BRS 975 c	BRS 777 a	BRS 753	BRS 756 A	BRS 1 B
SiO_2	57,30	57,25	56,86	55,41	56,71	55,19	55,19	54,36	54,14	53,43	53,05	50,80	49,80
TiO_2	1,04	1,01	0,88	0,86	0,95	0,79	0,93	0,80	0,76	0,99	0,85	0,64	1,68
Al_2O_3	17,33	16,82	16,65	17,91	17,18	17,12	15,04	14,47	16,81	17,40	18,83	14,39	16,34
Fe_2O_3	1,02	1,18	0,95	1,07	1,05	1,02	1,84	1,29	1,80	1,58	1,48	1,08	2,48
FeO	5,73	5,52	5,91	5,64	5,70	5,75	9,55	6,45	5,88	6,26	5,15	6,95	6,66
MnO	0,14	0,13	0,14	0,12	0,13	0,11	0,22	0,16	0,22	0,12	0,10	0,15	0,13
MgO	3,69	4,57	5,05	4,28	4,40	5,88	3,47	8,60	7,07	5,78	5,40	10,86	6,36
CaO	6,99	7,05	6,95	8,06	7,26	7,72	6,36	7,61	6,37	8,89	7,91	10,00	7,42
Na_2O	3,14	3,16	2,66	2,87	2,96	2,48	3,44	2,58	2,56	2,62	2,98	2,05	3,59
K_2O	1,72	1,59	1,48	1,57	1,59	1,88	2,18	1,26	1,10	1,11	1,99	0,48	1,70
P_2O_5	0,27	0,23	0,24	0,22	0,24	0,18	0,37	0,12	0,27	0,18	0,23	0,09	0,64
H_2O^+	1,28	1,34	1,81	1,52		1,69	1,37	1,74	2,47	1,54	1,65	2,10	3,05
H_2O^-	0,02	0,06	0,06	0,14		—	0,11	0,18	0,01	0,12	0,10	0,14	0,10
	99,67	99,91	99,64	99,67		99,81	100,07	99,62	99,46	100,02	99,72	99,73	99,95
	(p.p.m)												
Sr	n.d.	n.d.	250	n.d.		233	182	150	n.d.	269	290	197	n.d.
Rb	n.d.	n.d.	42	n.d.		50	51	24	n.d.	24	59	10	n.d.
Zr	n.d.	n.d.	157	n.d.		104	213	48	n.d.	56	90	36	n.d.
Y	n.d.	n.d.	9	n.d.		10	54	15	n.d.	14	7	7	n.d.
Rb/Sr	n.d.	n.d.	0,168	n.d.		0,214	0,280	0,160	n.d.	0,090	0,200	0,050	n.d.
K/Rb	n.d.	n.d.	292	n.d.		312	355	435	n.d.	384	280	398	n.d.
	Niggli												
si	174	169	167	159		152	157	138	147	140	142	114	127
al	30,9	29,2	28,9	30,2		27,7	25,2	21,7	26,8	26,9	29,8	19,1	24,6
fm	33,8	36,6	39,0	34,3		39,7	41,9	49,1	46,0	39,7	36,4	51,6	43,5
c	22,7	22,2	21,8	24,7		22,7	19,4	20,7	18,5	25,0	22,7	24,1	20,3
alc	12,5	12,0	10,3	10,8		9,9	13,4	8,4	8,6	8,5	11,2	5,2	11,7
k	0,26	0,25	0,26	0,26		0,32	0,29	0,24	0,22	0,21	0,30	0,13	0,24
mg	0,49	0,55	0,57	0,53		0,61	0,35	0,66	0,62	0,57	0,59	0,71	0,56
al-mg	18,4	17,2	18,6	19,4		17,8	11,8	13,3	18,2	18,4	18,6	13,9	12,9
	De La Roche												
R_1	2092	2114	2289	2102		2153	1615	2181	2216	2135	1813	2310	1362
R_2	1271	1310	1321	1426		1433	1148	1524	1362	1579	1484	1890	1429
S.I.	24,1	28,5	31,6	27,7		34,8	17,1	42,9	38,4	33,6	32,0	50,9	30,6

TABLE 2 - Chemical composition, Niggli — and De La Roche — values of some metamorphic dikes

Samples	BRS 775	BRS 13 A	BRS 786 A	BRS 783 c	BRS 751	BRS 909	BRS 783 B	BRS 780	BRS 1 A	BRS 893 b	BRS 16	BRS 780 A	BRS 773	BRS 780 B
SiO_2	76,14	75,87	74,36	73,41	72,66	70,29	69,36	64,12	60,73	57,78	57,83	55,72	55,08	47,57
TiO_2	0,09	0,10	0,24	0,08	0,20	0,08	0,29	0,60	0,68	0,86	1,05	1,01	0,96	0,63
Al_2O_3	13,59	13,81	14,57	14,31	14,66	17,20	15,74	16,15	17,79	16,75	15,07	16,15	19,32	14,96
Fe_2O_3	0,30	0,19	0,36	0,02	0,23	0,20	0,32	1,19	1,84	1,06	0,93	1,24	1,48	1,35
FeO	0,64	0,54	0,68	0,46	0,88	0,58	1,89	3,31	3,95	4,53	5,01	5,88	6,47	7,70
MnO	0,01	0,01	0,02	tr.	0,02	tr.	0,03	0,08	0,12	0,08	0,11	0,12	0,14	0,14
MgO	0,32	0,10	0,56	0,52	0,28	0,43	0,54	2,14	1,64	3,72	5,76	5,92	1,86	12,23
CaO	1,26	2,16	1,06	1,03	1,01	1,99	2,60	4,78	4,97	6,06	5,79	7,95	5,49	8,80
Na_2O	3,94	5,66	6,14	2,64	3,78	6,01	4,32	3,49	4,44	3,36	3,46	2,82	4,67	2,05
K_2O	2,25	0,82	1,19	6,94	5,10	1,76	3,52	2,41	1,98	2,86	2,43	0,91	2,63	1,40
P_2O_5	0,11	0,18	0,12	0,12	0,12	0,28	0,20	0,14	0,23	0,23	0,34	0,25	0,39	0,16
H_2O^+	0,70	0,52	0,44	0,37	0,48	0,73	0,64	1,11	1,11	2,18*	1,82	1,73	1,13	2,58
H_2O^-	0,10	0,11	0,09	0,12	0,10	0,10	0,13	0,10	0,16	0,13	—	0,07	0,16	0,14
	99,45	100,07	100,64	100,02	99,52	99,65	99,58	99,62	99,64	99,60	99,60	99,77	99,78	99,71
Niggli														
si	480	441	410	415	404	343	328	242	212	183	172	154	167	101
al	50,5	47,3	47,4	47,7	48,0	49,5	43,9	35,9	36,6	31,2	26,5	26,4	34,6	18,8
fm	7,9	4,4	9,3	6,6	7,5	6,2	12,5	26,1	25,3	32,2	40,4	40,9	28,6	55,0
c	8,5	13,4	6,3	6,2	6,0	10,4	13,2	19,3	18,6	20,5	18,5	23,6	17,9	20,1
alk	33,1	34,9	37,0	39,5	38,5	33,9	30,4	18,6	19,5	16,1	14,6	9,2	18,9	6,1
k	0,27	0,08	0,11	0,63	0,47	0,16	0,35	0,31	0,22	0,34	0,32	0,17	0,27	0,31
ti	0,40	0,40	1,00	0,30	0,80	0,30	1,00	1,70	1,80	2,00	2,40	2,10	2,20	1,00
mg	0,38	0,20	0,49	0,66	0,31	0,50	0,30	0,46	0,34	0,54	0,63	0,60	0,29	0,71
qz	248	201	162	157	150	107	106	68	34	18	14	18	8	25
De La Roche														
R_1	3120	2830	2462	2315	2271	2114	2197	2335	1838	1816	1869	2281	1159	1853
R_2	417	507	427	416	409	572	614	934	962	1161	1200	1461	1059	1842
S.I.	4,3	14	6,3	4,9	2,7	4,8	5,1	17,1	11,8	23,9	32,8	35,3	10,9	49,5

(*) + 0,51% CO_2

TABLE 3 - (*continued*)

Samples	BRS 949	BRS 974	BRS 941	BRS 898	BRS 979	BRS 973	BRS 951	BRS 945 d	BRS 929	BRS 973 b	BRS 978 b	BRS 978	BRS 981
SiO_2	71,50	70,20	70,11	69,50	68,83	68,71	66,39	62,71	58,95	52,06	48,40	49,98	56,62
TiO_2	0,39	0,37	0,41	0,27	0,38	0,51	0,60	1,24	0,74	1,93	0,50	0,45	1,15
Al_2O_3	14,90	14,91	15,65	14,75	15,21	15,57	16,31	15,98	18,00	13,74	8,40	15,40	16,20
Fe_2O_3	0,66	1,37	0,90	0,44	0,69	1,37	1,11	1,95	1,91	2,73	1,64	0,83	1,16
FeO	2,01	1,69	2,03	1,56	2,47	2,12	2,88	5,10	3,74	9,94	9,63	6,69	5,66
MnO	0,08	0,10	0,10	0,06	0,05	0,06	0,09	0,05	0,08	0,26	0,22	0,14	0,10
MgO	0,80	0,85	0,79	0,75	0,86	0,99	1,07	1,30	3,18	5,91	16,20	11,39	5,05
CaO	1,80	2,15	2,66	2,19	2,65	1,62	3,03	0,22	3,73	8,90	10,90	9,80	8,12
Na_2O	3,97	4,00	4,65	4,05	4,09	3,28	4,29	3,90	5,50	2,65	0,71	1,76	3,44
K_2O	2,96	3,14	1,67	3,57	2,45	3,48	2,30	6,01	1,66	0,30	0,12	0,39	0,25
P_2O_5	0,11	0,12	0,14	0,17	0,12	0,27	0,20	0,40	0,22	0,28	0,09	0,11	0,35
H_2O^+	0,95	1,12	0,85	2,37	1,89	1,64	1,34	1,38	2,02	1,44	3,23	2,76	1,38
H_2O^-	0,01	0,02	0,03	0,15	0,01	0,02	0,07	0,05	0,15	0,02	0,01	0,05	0,05
	100,14	100,04	99,99	99,83	99,70	99,65	99,68	100,16	100,05	100,29	99,88	99,75	99,53
	(p.p.m.)												
Sr	n.d.	243	n.d.	155	230	220	n.d.	n.d.	n.d.	102	5	152	947
Rb	n.d.	145	n.d.	136	73	95	n.d.	n.d.	n.d.	2	5	23	1
Zr	n.d.	162	n.d.	94	186	163	n.d.	n.d.	n.d.	119	28	58	15
Y	n.d.	5	n.d.	1	6	8	n.d.	n.d.	n.d.	23	5	14	20

TABLE 3 - Chemical composition of some paragneisses

Samples	BRS 945 c	BRS 975	BRS 950	BRS 936 B	BRS 976	BRS 953	BRS 936 A	BRS 928 B	BRS 931	BRS 964	BRS 945	BRS 935	BRS 928 A
SiO_2	79,60	76,20	75,64	74,29	73,85	72,74	73,61	73,13	73,03	72,96	72,37	72,32	71,58
TiO_2	0,46	0,08	0,19	0,19	0,20	0,32	0,15	0,18	0,20	0,17	0,33	0,22	0,28
Al_2O_3	10,60	12,83	13,16	14,22	14,06	14,71	13,79	15,45	13,95	14,06	14,37	14,53	15,33
Fe_2O_3	0,16	0,26	0,32	0,16	0,77	0,42	0,68	1,47	0,71	0,43	0,40	1,91	1,99
FeO	0,38	0,60	0,66	0,85	0,92	1,66	0,86	0,50	1,45	0,95	1,86	1,06	0,54
MnO	0,11	0,01	0,06	0,01	0,05	0,08	0,04	0,01	0,06	0,04	0,10	0,02	0,02
MgO	0,08	0,11	0,15	0,29	0,43	0,60	0,50	0,28	0,54	0,37	0,77	0,44	0,64
CaO	0,80	0,59	0,40	0,49	1,20	1,20	0,38	0,08	1,06	2,03	0,92	0,20	0,04
Na_2O	3,00	3,45	3,85	4,51	3,87	4,06	4,09	3,47	3,95	3,80	3,89	2,04	3,21
K_2O	3,64	5,18	4,38	3,92	3,90	3,73	4,41	4,67	3,84	2,61	3,78	5,42	4,40
P_2O_5	0,17	0,03	0,03	0,07	0,05	0,07	0,04	0,02	0,07	0,12	0,07	0,03	0,02
H_2O^+	0,97	0,39	1,18	0,53	0,72	0,76	1,01	0,97	0,79	2,37	0,99	1,46	1,49
H_2O^-	0,02	0,01	—	0,11	0,03	0,06	0,11	0,14	0,04	0,05	0,08	0,12	—
	99,99	99,74	100,02	99,64	100,05	100,41	99,67	100,37	99,69	99,96	99,93	99,78	99,54
	(p.p.m.)												
Sr	n.d.	183	140	127	222	n.d.	97	80	143	143	110	72	36
Rb	n.d.	53	122	109	122	n.d.	132	154	122	101	134	162	165
Zr	n.d.	67	65	115	88	n.d.	105	124	111	80	126	103	96
Y	n.d.	45	1	10	1	n.d.	6	3	3	3	8	—	1

GABBRO GNEISSES

These rocks are not widely diffused but they form conspicuous bodies (Cima Nera) in the north-eastern part of the geological map. Some strongly metamorphosed types still show clear gabbro textures. Generally they consist of fine grained dark metamorphites mostly composed of an abundant horneblende phase and of interstitial plagioclase granoblasts.

Amphiboles normally consisting of a Mg-horneblende (see Tab. 7), grows and develops at the expence of probable magmatic amphiboles and/or pyroxenes (Diallage ?), whose original twinning can still occasionally be recognized through the arrangement of ore minerals. The abundant segregation of magnetite and ilmenite suggests a greater abundance of Fe and Ti in the primary minerals. In some types there is also a fairly large quantity of biotite

showing the typical pleocroism (red brown-light yellow) of Mg-biotites.

Plagioclase is often zoned; it has a core of oligoclase composition (25-30% An) which develops around thickenings of clinozoisite microlites and is surrounded by a rim of albitic type (8-10% An).

Pistacite, sphene, ore minerals and, in some cases, garnet and apatite, are common accessories.

CHEMICAL FEATURES OF GNEISSIC ROCKS

In the following sections the analytical results of a large number of new analyses of massive and foliated orthogneisses, dikes and paragneisses are discussed.

Chemical data are reported in tabb. 1, 2 and 3. Trace elements from several significant samples have also been determined. Fig. 1 shows the exact location of the samples.

Ortogneisses

In order to define these lithotypes it was necessary to use chemical classifications which, however, are not always in good agreement. In addition to the identification of the «Niggli» types, the classification by Streckeisen and Le Maitre (1979) and the more recent one by De La Roche *et al.* (1980) have been used. In the classificative diagrams represented in fig. 2 and 3 we plotted every lithotype. In these diagrams, the Mesule gneisses are mainly concentrated in the granodiorite (Niggli's «farsunditic» magmas), leucoquartzdiorite («Trondjemites») and tonalite fields, even if there are both acid and basic differentiated terms.

This resembles a calc-alkalic sequence (see diagram AFM and Niggli's variation diagrams), in which some lithotypes tend to assume an alkali affinity. These anomalies have already been pointed out in the Tauern area (Bianchi, 1934) and in other Hercynic plutons (D'Amico, 1976; Visonà personal communication). Most probably they have been caused by metasomatic processes, developed during metamorphism which does not always exibit the isochemical characters usually attributed to it. Such phenomena are fairly evident in those rocks particularly affected by dynamic stress and later by tardocynematic blastesis; locally they also occur to a smaller degree in massive types. The contents in alkalies and other elements (Fe, Ca, Mg, etc.) are different in seemingly identical samples which are very close to each other in the field. This feature confirms the above assumption. The Na_2O/ K_2O ratio variation (Fig. 6) within a single magmatic group also confirms such a hypothesis. Although these chemical modifications have not masked the alkali-calcic affinity of the magmatics, the former must not be underestimated in a correct discussion.

The dikes mostly concordant with the country foliation are both acid and basic in composition even

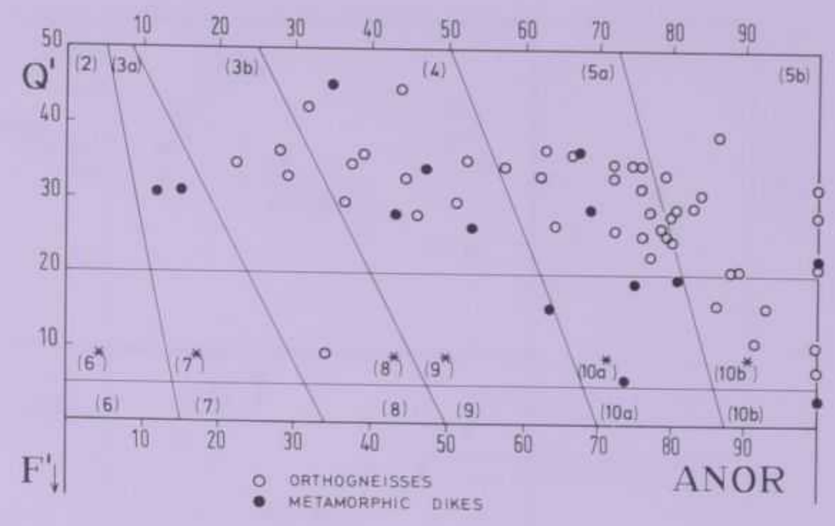


Fig. 2 - Streckeisen's classificative diagram (mesonorm calculated by Mielke-Winkler). Empty circles = masses; full circles = dikes.

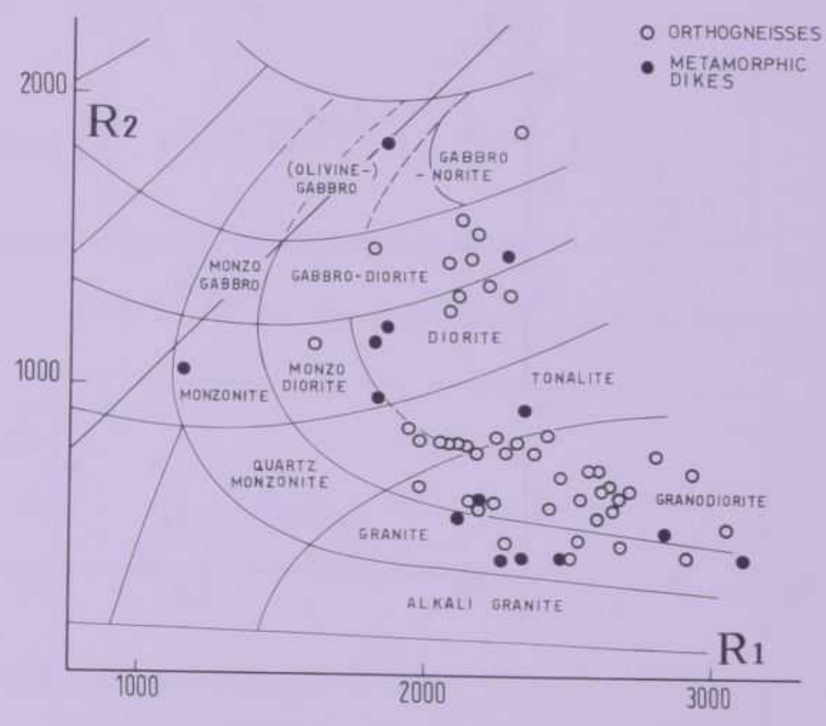


Fig. 3 - De La Roche's R_1 - R_2 diagram. For the symbols see Fig. 2.

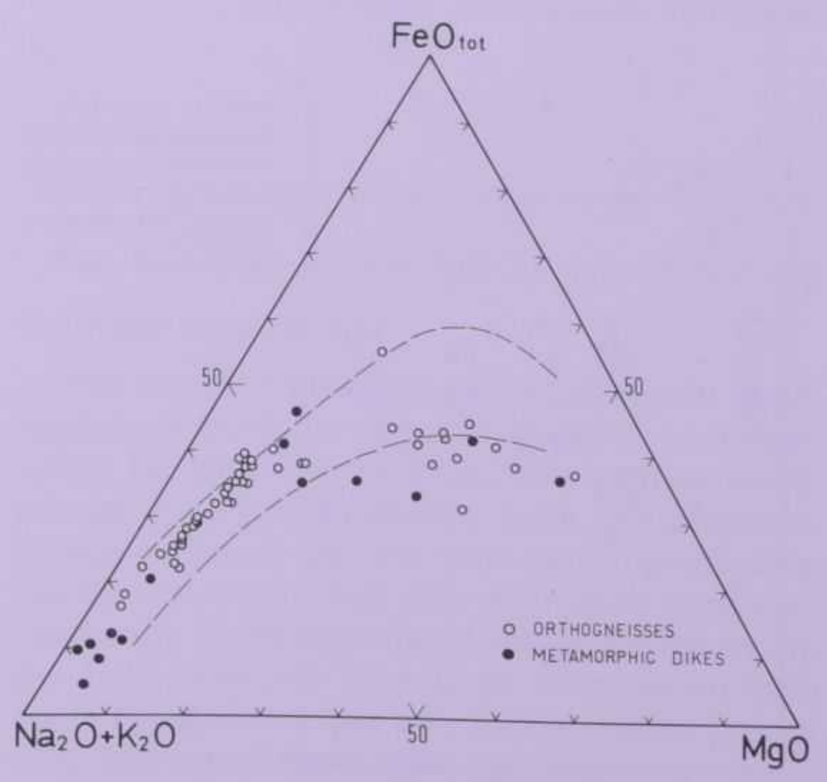


Fig. 4 - A F M diagram. The two dotted lines define the field of the calcalkaline series. For the symbols see Fig. 2.

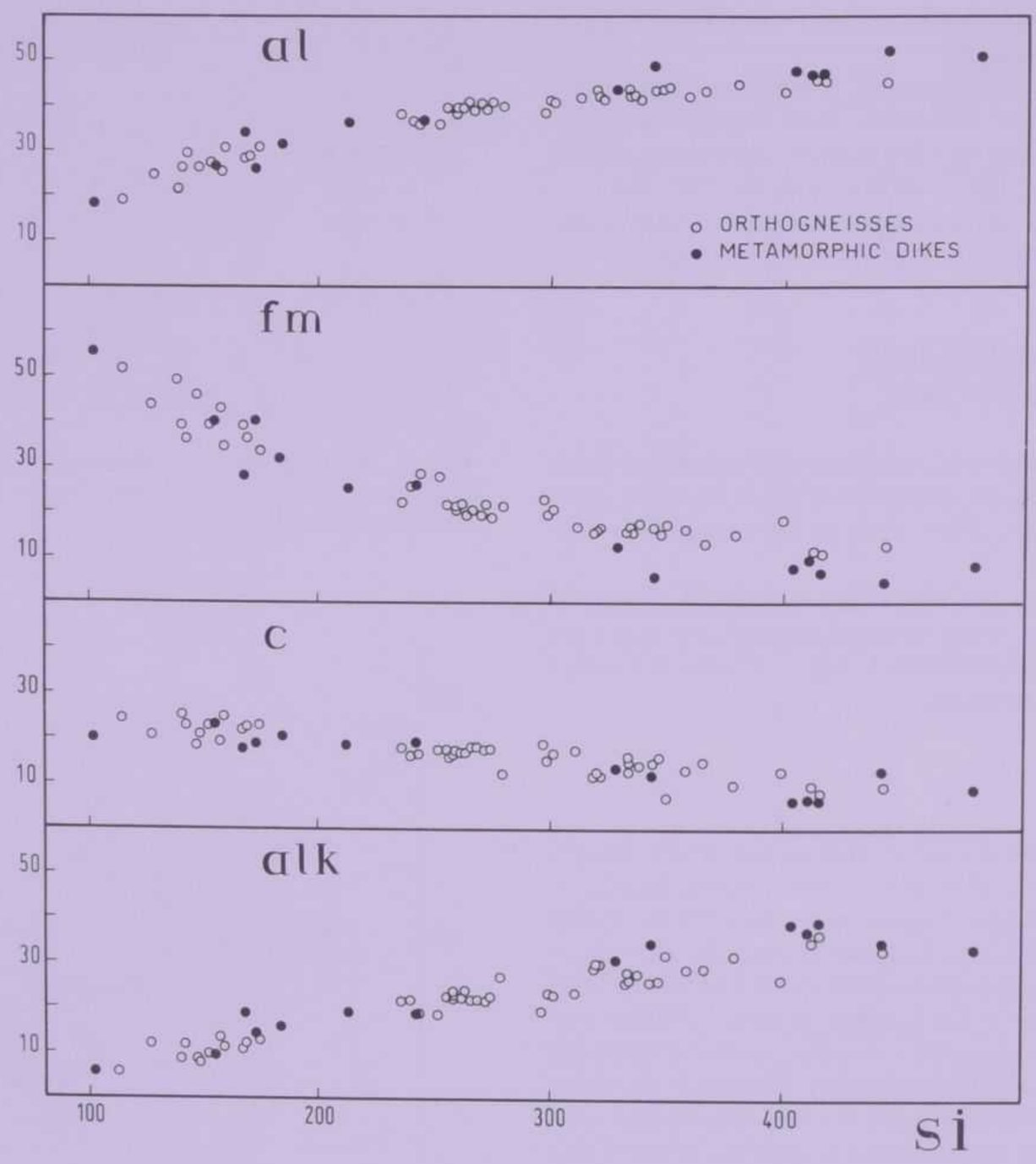


FIG. 5 - NIGGLI's variation DIAGRAMS. For the symbols see Fig. 2.

if undifferentiated terms occur (see Tab. 2 and Fig. 6). Chiefly in the more deformated areas they also underwent metasomatic phenomena.

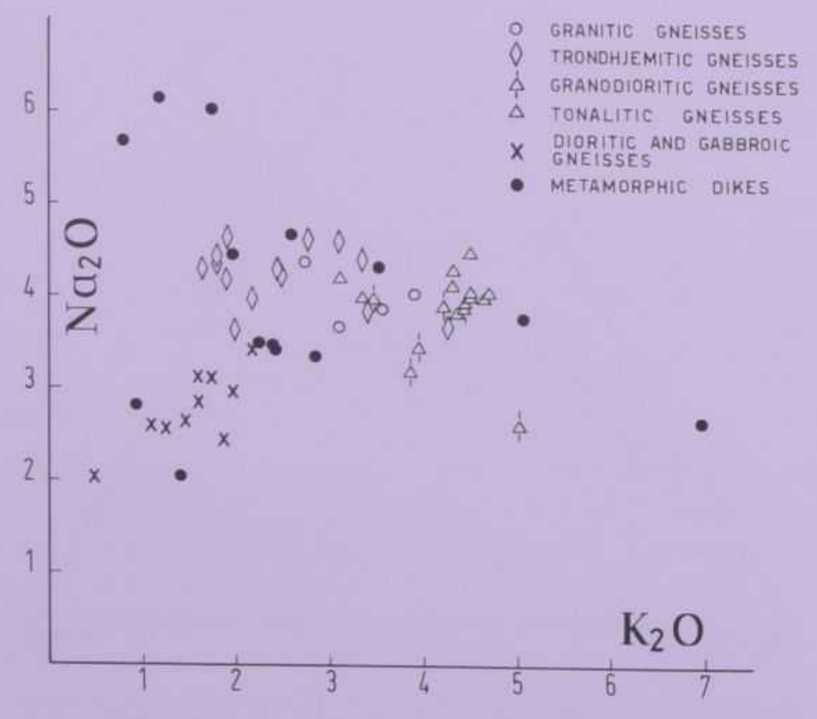


FIG. 6 - Na_2O - K_2O variation diagrams.

Tab. 4 shows the means of the analyses of granitoid gneisses in the Aurine Alps quoted from various authors. The comparison with our data is very satisfactory, except for the different level of iron oxidation. Furthermore a comparison between major and trace elements has made it possible to obtain significant information which is not achievable by a simple correlation of major elements.

In the Sr/SI and Zr/SI diagrams (Fig. 7a and 7b) granites and granodiorites show a good linear correlation while, on the contrary, gabbros and gabbrodiorites exhibit a discordant trend with remarkable scattering. In the Ti/Zr and Rb/Zr diagrams (Fig. 8a and 8b) conclusions are analogous; the linear inverse correlation of granites and granodiorites is in contrast with gabbros and gabbrodiorites.

In conclusion, the geochemical affinities in both massive and foliated metagranitoids and in dikes show a typical differentiated alkali-calcic series. Although the more basic types belong to the same series, they show a sharp compositional gap in comparison with the intermediate terms (see variation diagrams) as well as some anomalies in the content

TABLE 4 - Means analyses of granitoid gneisses from the Aurine Alps

	Granite gneisses		Granodiorite and tonalite gneisses	
	a ($\bar{x} = 12$)	b ($\bar{x} = 7$)	c ($\bar{x} = 8$)	d ($\bar{x} = 17$)
SiO_2	72,89	73,85	65,60	65,60
TiO_2	0,23	0,17	0,52	0,60
Al_2O_3	14,15	14,00	16,00	16,44
Fe_2O_3	0,97	0,34	1,53	0,91
FeO	0,84	1,17	2,59	3,53
MgO	0,39	0,38	1,32	1,19
CaO	1,44	1,31	3,96	3,88
Na_2O	3,80	3,76	4,22	4,22
K_2O	4,23	3,94	2,73	2,10

Analyses from:

a) BIANCHI, 1934, pg. 20 (n. 5 Anal.)
MORTEANI, 1971, tabb. 3 and 5 (n. 6 Anal.)
KARL, 1959 (n. 1 Anal.)

b) BIANCHI, 1934, pg. 5 and 16 (n. 4 Anal.)
MORTEANI, 1971, Tab. 1 (n. 3 Anal.)
KARL, 1959 (n. 1 Anal)

c) this work

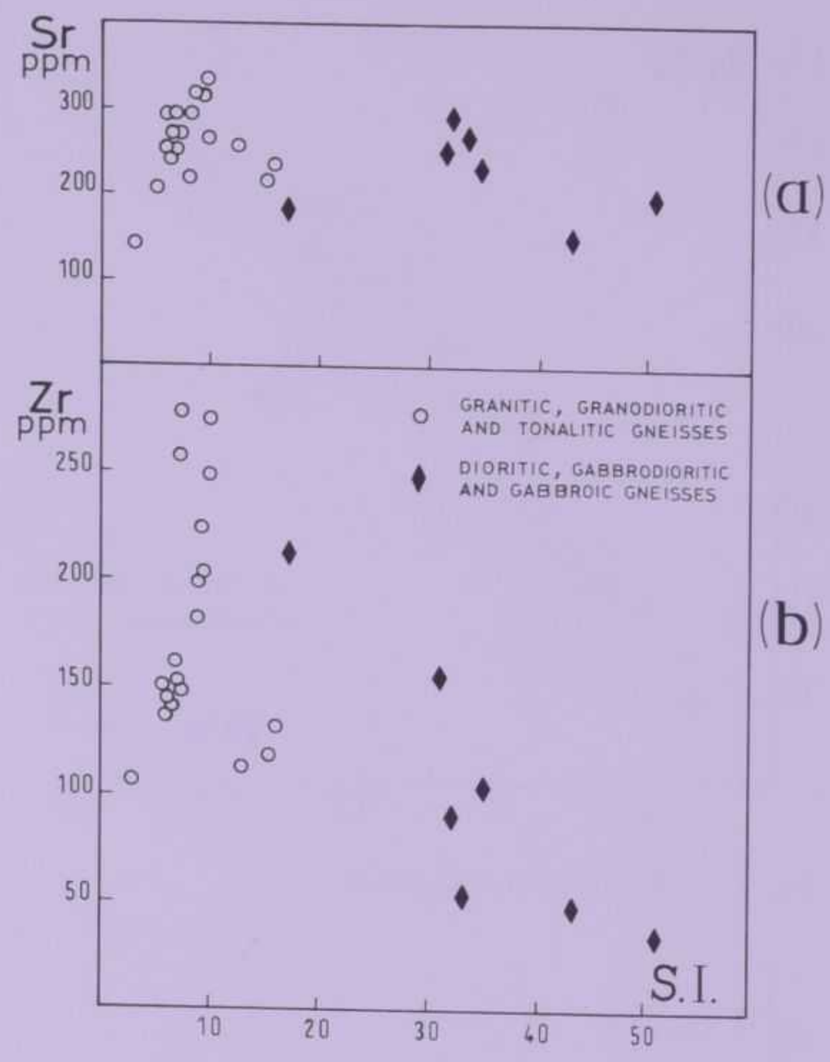
d) this work

TABLE 5 - Means of Ortho- and Paragneisses

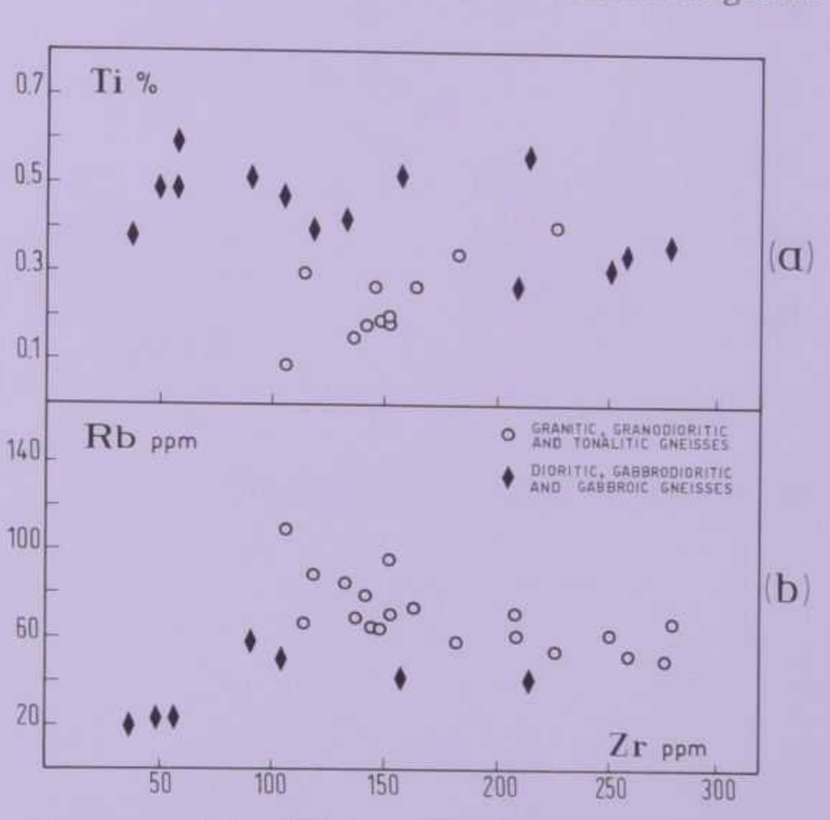
	Ortho- ($\bar{x} = 14$)	σ	Para- ($\bar{x} = 18$)	σ
SiO_2	71,8	1,6	73,2	2,3
TiO_2	0,3	0,1	0,3	0,1
Al_2O_3	14,6	0,7	14,2	1,2
Fe_2O_3 tot.	2,8	0,5	2,1	0,9
MgO	0,6	0,2	0,5	0,3
CaO	2,2	1,2	1,0	0,9
Na_2O	4,1	0,3	3,7	0,6
K_2O	2,6	0,9	3,8	1,1
Sr ppm	238		133	
Rb	77		127	
Zr	143		104	

of some trace elements. Perhaps these geochemical features indicate a mantle origin in the basic melts while acid to intermediate melts could have a crustal origin.

The basic and granitoid bodies intruded at different times. These polyphasic intrusions are confirmed in the field where it is evident that the basic bodies intruded before the granitic ones.



FIGS. 7a and 7b - Sr-SI and Zr-SI variation diagrams.



FIGS. 8a and 8b - Ti-Zr and Rb-Zr variation diagrams.

COUNTRY PARAGNEISSES

The covers of Hercynic granitoids consist of paragneisses which are rather monotonous in composition. Paraderivates have probably been metamorphosed in a pre-Westfalian time and psephitic-psammitic sized, they are quite easily recognizable. On the contrary, when only psammitic sized they can hardly be distinguished from orthoderivates in the field. However microscope observations have made it possible to get a further and more precise identification of these rocks.

Chemical analyses, furthermore, allowed us to distinguish their arkosic origin and other distinctive

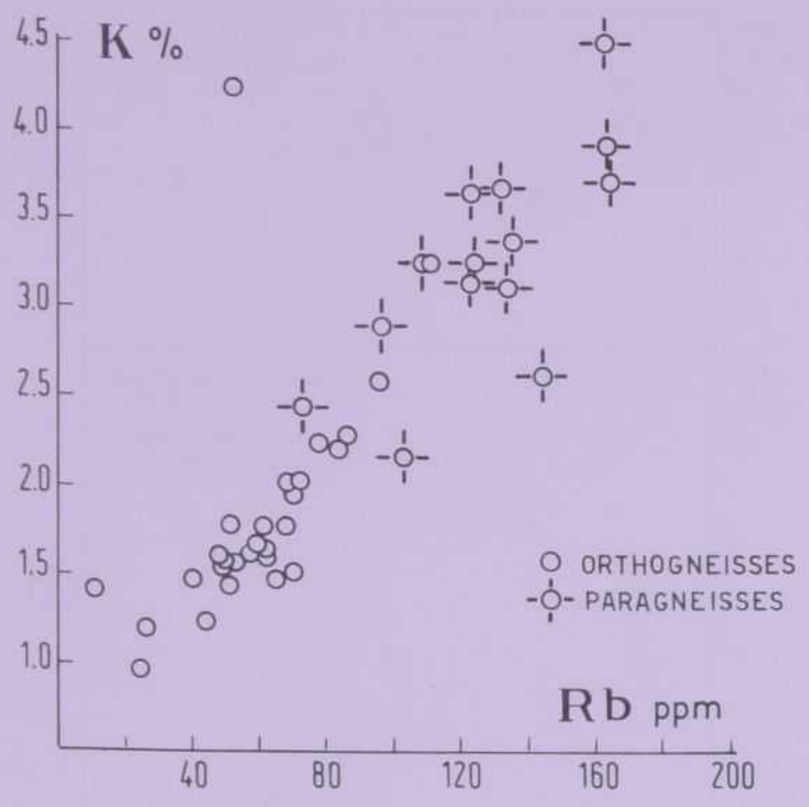


FIG. 9 - K-Rb variation diagrams.

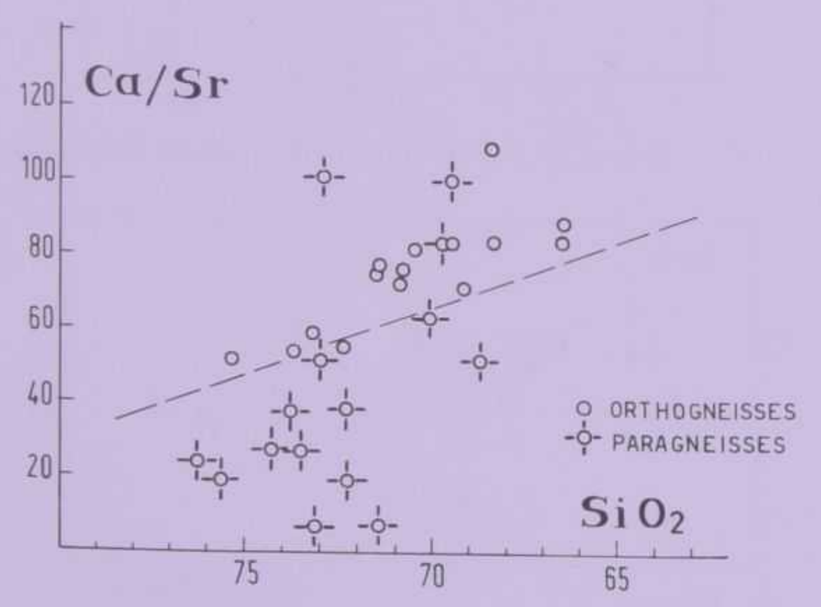


FIG. 10 - Ca/Sr - SiO_2 variation diagrams.

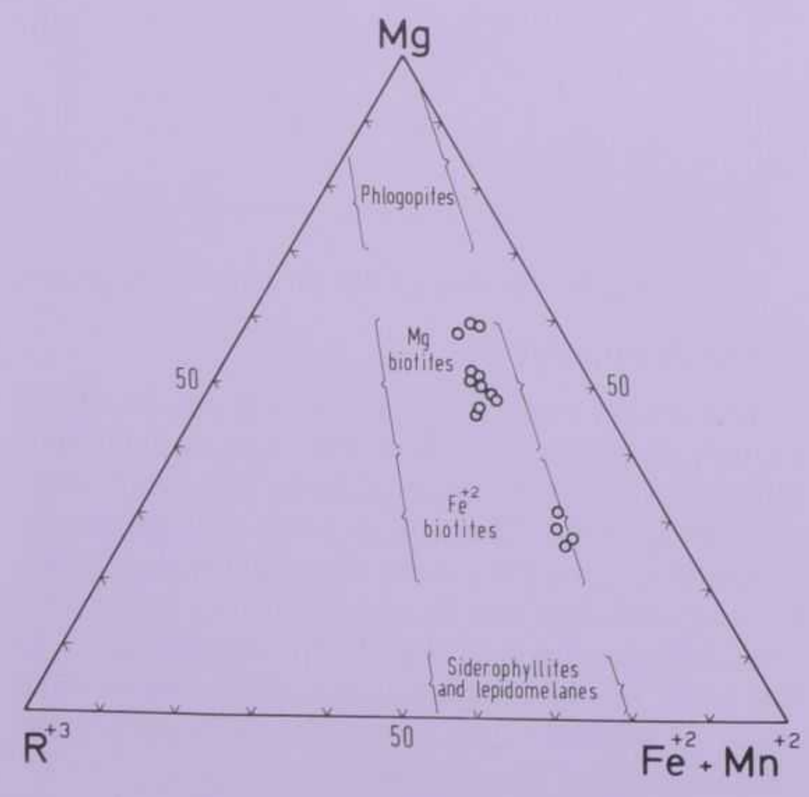


FIG. 11 - Classificative-diagram of biotites by FORSTER (1960).

features. First a comparison of the major elements (see Tabb. 1 and 3) indicates that metarkoses are far richer in silica and have a high and variable alkali content. Types having K > Na contents are frequent; this is unusual in the metagranitoids.

In tab. 5 mean analyses of ortho- and paraderivates having a $SiO_2 \geqq 70\%$ content are compared. Country rocks show greater variations in oxide content, have higher silica and K contents, while Ca, Na and Fe contents are lower. Immobile considered elements (Al and Ti) do not concentrate in metasediments: it is probable, therefore, that the sedimentary differentiation and alteration processes have been rather slight. Trace elements follow the dynamics of major elements to which they are closely correlated in the geochemical processes. In metasediments, Rb, an element coherent with K, shows double values on average. Mean contents of Sr and Zr, the latter believed to be practically immobile in alteration processes, are constant in the two groups. However comparison between major and trace elements shows unusual dynamics. K and Rb contents in para- and orthoderivates are plotted in fig. 9. The linear correlation is good, even if the dots are more widely scattered in paraderivates.

Due to the similar slope the regression line shows that the two elements have analogous geochemical behaviour. However, the groups occupy quite different fields. In fig. 10 Ca/Sr ratio is correlated with silica the latter being equal; paraderivates show clearly lower values and are arranged in a field quite separate from orthoderivates. Therefore such metamorphites can easily be distinguished even from the geochemical viewpoint.

CHEMICAL FEATURES OF CHARACTERISTIC MINERALS

Using an electron microprobe provided with an energy scattering spectrometer ETEC-AUTOSCAN-AUTOSPEC (1) we have studied some minerals (micas, amphiboles, garnets and carbonates), belonging either to the granitoid complex or to the covers. The common methodologies (wet analises, AA and FX) were used for some of them, previously separated and concentrated by magnetic separator and heavy liquids.

BIOTITES

Microprobe analyses of biotites from ortho-and paraderivates are shown in tab. 6. To classify them we used FORSTER's diagram (Fig. 11).

(1) Reference patterns: Mg - diopside; Si - quartz; Al - corundum; Ca, Na, Ti - Augite (Kalamani); K - amphibole EU 71 (kaersutite); Cr, Mn, Fe - pure elements. Calculation program for absorbance correction from MASON *et al.* (1959), partially modified.

TABLE 6a - Selected microprobe analyses of micas

Samples	Biotites														
	BRS 761		BRS 776 b		BRS 786c		BRS 912		BRS 895			BRS 955			BRS 976
SiO_2	38,79	38,81	37,94	38,09	39,06	40,16	39,20	38,92	39,45	39,70	39,57	36,96	37,06	36,83	37,38
TiO_2	2,23	1,82	2,44	1,88	1,73	1,99	2,09	2,01	1,67	1,54	1,60	3,19	2,98	3,46	2,44
Al_2O_3	17,56	18,32	17,18	17,23	18,13	17,66	18,69	18,87	18,71	18,91	18,90	16,98	16,86	16,22	17,03
FeO tot.	18,16	18,43	23,97	24,36	16,79	16,18	17,49	17,79	15,94	16,02	15,55	26,01	25,70	26,16	25,73
MnO	0,32	0,17	0,39	0,36	0,35	0,20	0,34	0,23	0,31	0,22	0,19	0,41	0,25	0,28	0,38
MgO	13,24	13,68	8,56	8,53	14,93	14,23	12,80	12,74	14,19	13,87	13,93	6,54	7,27	6,98	7,91
K_2O	9,69	8,76	9,53	9,55	9,01	9,58	9,39	9,44	9,74	9,75	10,27	9,91	9,88	10,06	9,12
Numbers of Ions on the Basis of 22 Oxygens															
Si	5,565	5,534	5,597	5,626	5,540	5,680	5,529	5,549	5,583	5,612	5,601	5,535	5,537	5,532	5,577
Al^{IV}	2,435	2,466	2,403	2,374	2,460	2,320	2,421	2,451	2,417	2,388	2,399	2,465	2,463	2,468	2,443
Al^{VI}	0,534	0,613	0,584	0,625	0,571	0,614	0,714	0,720	0,704	0,763	0,754	0,532	0,506	0,403	0,541
Ti	0,241	0,195	0,271	0,209	0,185	0,212	0,224	0,216	0,178	0,164	0,170	0,359	0,335	0,391	0,273
Fe^{2+}	2,179	2,198	2,957	3,009	1,992	1,914	2,082	2,121	1,887	1,894	1,841	3,258	3,211	3,286	3,199
Mn	0,039	0,021	0,049	0,045	0,042	0,024	0,041	0,028	0,037	0,026	0,023	0,052	0,032	0,036	0,048
Mg	2,831	2,908	1,882	1,878	3,156	3,000	2,716	2,707	2,993	2,923	2,939	1,460	1,619	1,563	1,753
	5,824	5,935	5,743	5,766	5,946	5,774	5,777	5,792	5,799	5,770	5,727	5,661	5,703	5,679	5,814
K	1,770	1,593	1,793	1,799	1,630	1,730	1,705	1,717	1,758	1,758	1,854	1,893	1,883	1,927	1,730

Rocks: Gabbro-diorite gneiss (BRS 761, BRS 776b, BRS 786c); Diorite gneiss (BRS 912, BRS 895); Granodiorite gneiss (BRS 955); Paragneiss (BRS 976).
Analist: P. DA ROIT

TABLE 6b - (*continued*)

Samples	Biotites					Phengites								
	BRS 964		BRS 981			BRS 976		BRS 928		BRS 935			BRS 945	
SiO_2	37,11	36,74	40,05	40,41	40,08	54,08	54,18	49,92	50,50	50,04	49,96	50,15	50,86	51,78
TiO_2	1,83	2,27	1,29	1,40	1,33	0,33	0,41	0,71	0,47	0,45	0,57	0,55	1,40	1,28
Al_2O_3	14,75	15,19	16,84	16,61	17,24	27,22	27,77	30,96	31,08	29,38	29,37	29,49	31,45	30,36
FeO tot.	27,33	26,80	14,81	14,52	14,41	4,99	4,92	6,78	6,69	7,92	8,13	8,15	3,92	3,80
MnO	0,63	0,38	0,30	0,15	0,15	0,19	0,30	0,06	0,10	0,08	0,16	—	0,06	0,14
MgO	8,58	8,90	16,55	16,84	16,70	2,26	1,88	0,88	0,82	0,83	0,80	0,91	1,44	1,67
K_2O	9,76	9,73	10,15	10,07	10,09	10,93	10,53	10,60	10,34	11,30	11,00	10,76	10,87	10,96
Numbers of Ions on the Basis of 22 Oxygen														
Si	5,613	5,538	5,663	5,696	5,647	6,939	6,932	6,480	6,530	6,559	6,548	6,556	6,512	6,625
Al^{IV}	2,387	2,462	2,337	2,304	2,353	1,061	1,068	1,520	1,470	1,441	1,452	1,444	1,488	1,375
Al^{VI}	0,242	0,237	0,469	0,455	0,510	3,056	3,119	3,126	3,266	3,098	3,085	3,099	3,258	3,203
Ti	0,208	0,257	0,137	0,148	0,141	0,032	0,039	0,069	0,046	0,044	0,056	0,054	0,135	0,124
Fe^{2+}	3,457	3,378	1,751	1,752	1,698	0,535	0,526	0,736	0,722	0,868	0,891	0,891	0,420	0,407
Mn	0,081	0,049	0,036	0,018	0,018	0,021	0,033	0,007	0,011	0,009	0,018	—	0,007	0,015
Mg	1,934	2,000	3,488	3,538	3,507	0,432	0,359	0,170	0,158	0,162	0,156	0,177	0,275	0,318
	5,922	5,921	5,881	5,871	5,874	4,075	4,076	4,198	4,203	4,181	4,206	4,221	4,095	4,067
K	1,883	1,871	1,831	1,811	1,814	1,789	1,719	1,770	1,706	1,890	1,839	1,794	1,775	1,789

Rocks: Paragneiss (BRS 964, BRS 981, BRS 976, BRS 928, BRS 935, BRS 945)

Analist: P. DA ROIT

Even if their Fe_2O_3 content is not known, the structural formula indicates that the group of six-coordinated elements always presents a deficit of charge. This fact excludes «a priori» the possibility of inserting Fe^{3+} in the formula. The presence of this oxidated element, however, would not prevent the use of this classification diagram.

The compositive variations seem to influence some optical features, among which the absorbance pattern. Fe-biotites have a pleocroism ranging from rusty dark brown ($\gamma = \beta$) to light yellow-brown (α); pleocroism of Mg-biotites varies from red-brown to light yellow-green. These optical features allow a simple separation into two groups.

Biotites in the granite and granodiorite gneisses are essentially Fe-biotites, while those in the diorite, gabbrodiorite and gabbro gneisses are Mg-biotites. HENRICH (1946) and already seen that, in plutonic rocks with a granitic composition, the FeO content of the biotites is markedly higher, and that, in the granodioritic, dioritic and gabbric terms, the MgO progressively increases.

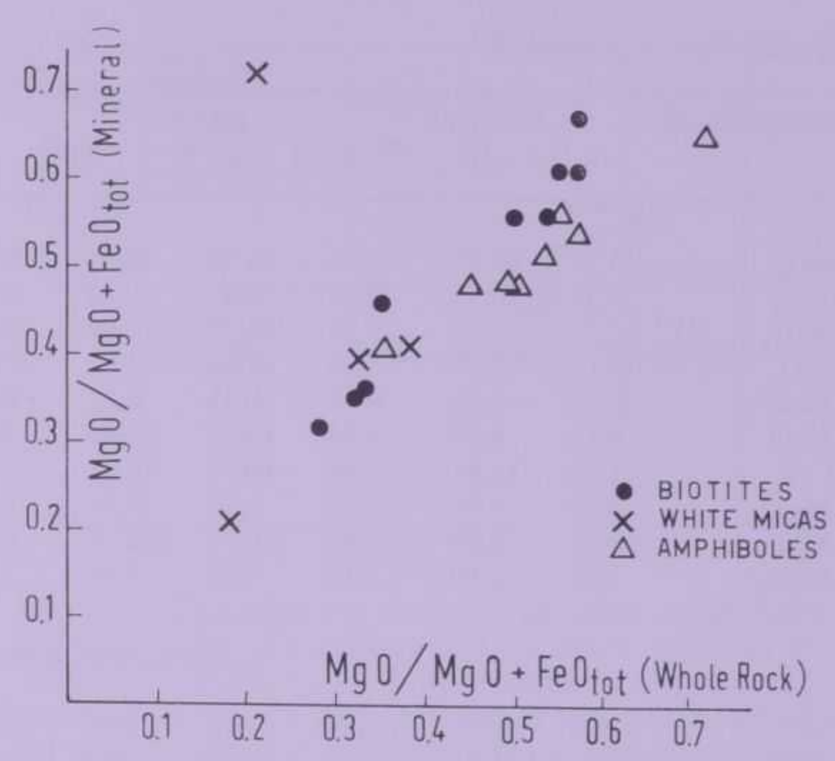


FIG. 12 - Molar ratio MgO/MgO + FeO whole rock-mineral.

TABLE 7a - Selected microprobe analyses of amphiboles

Samples	BRS 776 (c	BRS 776 (r'	BRS 776 (c'	BRS 786 (c	BRS 786 (r	BRS 786 (c'	BRS 786 (r'	BRS 895 (c	BRS 895 (r'	BRS 895 (r''	BRS 761 (c	BRS 761 (r
SiO_2	46,50	45,54	45,91	47,23	45,90	46,98	45,53	47,32	45,86	46,13	46,82	45,04
TiO_2	0,40	0,22	0,39	1,06	0,41	0,55	0,31	0,16	0,43	0,21	0,50	0,49
Al_2O_3	10,57	11,06	11,04	14,21	14,94	13,70	15,59	14,43	15,80	15,05	14,86	15,34
FeO_{tot}	20,36	20,95	20,58	13,34	15,02	14,66	15,28	14,78	14,87	14,63	14,87	16,12
MnO	0,49	0,45	0,40	0,29	0,32	0,45	0,42	0,28	0,25	0,65	0,38	0,34
MgO	8,40	8,13	8,02	11,07	10,24	11,16	9,81	10,78	9,89	9,64	9,33	10,00
CaO	11,31	11,89	11,82	11,74	11,47	11,80	11,67	10,43	11,88	12,20	11,43	11,13
Na_2O	1,11	0,74	1,04	0,71	1,18	0,39	0,94	1,53	0,68	1,16	0,80	1,10
K_2O	0,85	1,03	0,81	0,37	0,41	0,33	0,47	0,29	0,35	0,32	0,45	0,45
Fe_2O_3*	4,99	5,11	3,66	3,78	5,55	7,00	5,33	7,55	4,88	1,60	2,60	8,45
Numbers of Ions on the Basis of 23 Oxygens												
Si	6,775	6,671	6,726	6,624	6,483	6,583	6,442	6,607	6,466	6,576	6,662	6,353
Al^{IV}	1,225	1,329	1,274	1,376	1,517	1,417	1,558	1,393	1,534	1,424	1,338	1,647
	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000
Al^{VI}	0,590	0,580	0,632	0,973	0,983	0,844	1,042	0,981	1,092	1,105	1,154	0,903
Ti	0,044	0,024	0,043	0,112	0,044	0,058	0,033	0,017	0,046	0,023	0,054	0,052
Fe^{3+}	0,547	0,563	0,404	0,399	0,590	0,738	0,567	0,793	0,518	0,172	0,289	0,897
Fe^{2+}	1,933	2,003	2,117	1,166	1,188	0,978	1,240	0,932	1,235	1,573	1,479	1,004
Mn	0,060	0,056	0,050	0,034	0,038	0,053	0,050	0,033	0,030	0,078	0,046	0,041
Mg	1,826	1,774	1,757	2,316	2,157	2,329	2,068	2,244	2,079	2,049	1,978	2,103
	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000
Ca	1,766	1,866	1,855	1,764	1,736	1,772	1,768	1,560	1,795	1,863	1,743	1,682
Na	0,234	0,134	0,145	0,236	0,264	0,106	0,232	0,414	0,186	0,137	0,221	0,301
	2,000	2,000	2,000	2,000	2,000	1,878	2,000	1,974	1,981	2,000	1,964	1,983
Na	0,080	0,076	0,150	—	0,059	—	0,026	—	—	0,184	—	—
K	0,158	0,192	0,151	0,023	0,074	0,059	0,085	0,052	0,063	0,058	0,082	0,081
	0,238	0,268	0,301	0,023	0,133	0,059	0,111	0,052	0,063	0,241	0,082	0,081

Fe_2O_3* = calculated; c) = core; r) = rim
Analist: P. DA ROIT

TABLE 7b - (*continued*)

Samples	BRS 912 (c	BRS 912 (r	BRS 912 (r''	BRS 957 (c	BRS 957 (r	BRS 973 b (c	BRS 973 b (r	BRS 973 b (c'	BRS 973 b (r'	BRS 978 b (c	BRS 978 b (c'	BRS 978 b (r	BRS 978 b (r'
SiO_2	45,43	43,89	45,16	48,10	48,91	46,47	47,29	44,58	45,82	49,48	50,24	49,53	49,90
TiO_2	0,41	0,35	0,38	0,43	0,44	0,39	0,48	0,33	0,34	0,60	0,36	0,29	0,25
Al_2O_3	16,30	17,22	16,10	13,77	12,90	11,93	12,12	15,53	14,33	12,81	10,67	12,23	11,67
FeO	16,17	15,55	15,66	12,44	13,62	17,00	16,38	17,03	16,69	11,72	12,36	12,71	12,15
MnO	0,38	0,26	0,43	0,43	0,21	0,30	0,36	0,47	0,52	0,29	0,24	0,25	0,36
MgO	8,12	8,67	8,74	12,51	11,86	9,58	9,99	8,60	8,81	13,01	13,75	12,38	13,37
CaO	11,96	11,81	11,48	10,75	10,03	11,42	11,89	11,34	11,07	11,20	11,08	10,28	11,22
Na_2O	0,79	1,64	1,56	1,33	1,71	1,47	1,14	1,66	2,00	0,58	1,13	2,04	0,88
K_2O	0,46	0,60	0,50	0,24	0,31	0,43	0,34	0,46	0,42	0,31	0,27	0,28	0,20
Fe_2O_3*	1,85	2,10	2,30	5,55	7,00	3,10	2,70	4,40	2,70	6,50	6,40	4,70	6,70
	Numbers of Ions on the Basis of 23 Oxygens												
Si	6,498	6,297	6,458	6,648	6,786	6,745	6,768	6,397	6,582	6,808	6,937	6,890	6,884
Al^{IV}	1,502	1,703	1,542	1,352	1,214	1,255	1,232	1,603	1,418	1,192	1,063	1,110	1,116
	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000
Al^{VI}	1,246	1,209	1,171	0,891	0,395	0,786	0,812	1,024	1,009	0,885	0,677	0,895	0,782
Ti	0,044	0,038	0,041	0,045	0,046	0,043	0,052	0,036	0,037	0,062	0,037	0,030	0,026
Fe^{3+}	0,199	0,227	0,248	0,785	0,731	0,339	0,291	0,475	0,292	0,673	0,665	0,492	0,696
Fe^{2+}	1,734	1,639	1,625	0,652	0,349	1,724	1,670	1,569	1,713	0,676	0,763	0,986	0,705
Mn	0,046	0,032	0,052	0,050	0,025	0,037	0,044	0,057	0,063	0,034	0,028	0,029	0,042
Mg	1,731	1,855	1,863	2,577	2,454	2,071	2,131	1,839	1,886	2,670	2,830	2,568	2,749
	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000
Ca	1,833	1,815	1,759	1,592	1,491	1,776	1,823	1,744	1,704	1,651	1,643	1,532	1,658
Na	0,167	0,185	0,241	0,356	0,460	0,224	0,177	0,256	0,296	0,155	0,303	0,468	0,235
	2,000	2,000	2,000	1,948	1,951	2,000	2,000	2,000	2,000	1,806	1,946	2,000	1,893
Na	0,052	0,271	0,192	—	—	0,190	0,139	0,206	0,261	—	—	0,082	—
K	0,084	0,110	0,091	0,042	0,055	0,080	0,062	0,084	0,077	0,054	0,048	0,050	0,035
	0,136	0,381	0,283	0,042	0,055	0,270	0,201	0,290	0,338	0,054	0,048	0,132	0,035

Fe_2O_3* = calculated; c) = core; r) = rim
Analist: P. DA ROIT

The persistence of these features in biotites of corresponding metamorphics suggests that the composition of the protoliths still control the chemistry of these micas, physical features being equal.

The trend of MgO/MgO + FeO whole rock-biotites molar ratio (Fig. 12) emphasizes a clear direct linear correlation in the biotites both from ortho- and paraderivates.

White micas in the granitoid gneisses and in the paragneisses of the covers have rather uniform optical features. They are essentially colourless or there are light green-pale yellow tonalities. The 2V is near 30° with a phengite chemical composition (see Tab. 6b). The MgO/MgO + FeO whole rock-white mica molar ratio exhibits a good linear correlation (Fig. 12); this suggests that the composition of the primary rock is a conditioning factor.

AMPHIBOLES

Amphiboles both in the diorite and gabbro gneisses and in the metasediments of the cover, have been investigated. In tab. 7 analyses both of core and rims of single crystals are reported. Structural formula have been obtained according to LEAKE's proposal (1) (1978). These crystallochemical conditions are not satisfactory (see also HAWTHORNE, 1983), as can be seen comparing the analyses by traditional methods of the two amphiboles (BRS 957A and BRS 973b) which were separated and concentrated by heavy liquids. The comparison emphasizes that Fe^{3+} content calculated by the above mentioned method, is overestimated, and therefore the average Mg/Mg + Fe^{2+} tot. ratio turns out to be higher. In despite of these difficulties, these amphiboles can mostly be classified (LEAKE, 1978) as Mg-horneblendes and as tschermachites (see Fig. 13).

Furthermore, microprobe analyses reveal that there are no great variations between core and rims;

(1) Formula obtained on basis 23 ≡ (O, F, OH), through the extrapolation of the Fe_2O_3 values from the charge-balance of octahedric and tetrahedric positions which sum on 13, assuming that all Ca, Na and K are in the B and A sites.

TABLE 7c (*continued*)

Samples*	BRS 957A	BRS 973b
SiO_2	45,62	45,05
TiO_2	0,51	0,31
Al_2O_3	13,93	13,76
Fe_2O_3	2,26	1,69
FeO	10,08	15,39
MnO	0,32	0,36
MgO	12,12	8,80
CaO	10,42	10,54
Na_2O	1,46	1,40
K_2O	0,30	0,35
H_2O^+	2,34	1,82
F^-	0,09	0,09
	99.45	99.56
Numbers of Ions on the Basis of 24 Oxygen		
Si	6,575	6,673
Al^{IV}	1,425	1,327
	8,000	8,000
Al^{VI}	0,941	1,075
Ti	0,055	0,034
Fe^{3+}	0,245	0,189
Fe^{2+}	1,215	1,907
Mn	0,040	0,045
Mg	2,603	1,942
	5,099	5,152
Ca	1,610	1,673
Na	0,390	0,327
	2,000	2,000
Na	0,018	0,078
K	0,056	0,066
	0,074	0,144
OH	2,250	1,795
F	0,041	0,040
	2,291	1,835

* Amphiboles analized with traditional methods
Analist: A. GIARETTA

this is also confirmed by optical observations. As the composition of the terms of this family varies, pleocroism does not noticeably change, and only in Mg-amphiboles is a slight attenuation of the greenish tonalities observable. As occurs for the micas, also amphiboles are clearly influenced by the whole rock composition. The diagram in fig. 12 shows the linear direct correlation between some elements of the mineral and the whole rock; this indicates the chemical conditioning of amphiboles during their metamorphic growth.

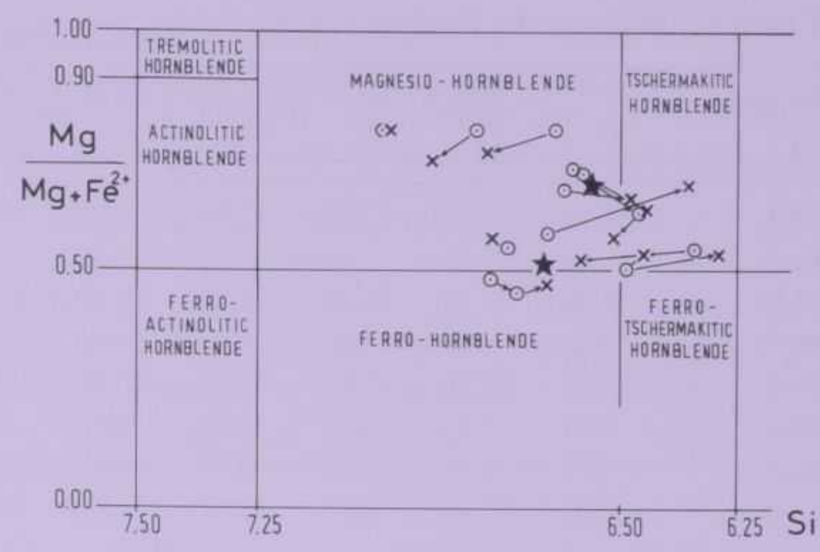


FIG. 13 - Classification diagram of calcic amphiboles (LEAKE, 1978). $(Ca + Na)_B \geq 1{,}34$; $Na < 0{,}6$; $(Na + K)_A < 0{,}5$ and $Ti \leq 0{,}5$. Empty circles = core compositions; small cross = compositions of rims and peripherical zones; stars = composition of two amphiboles analyzed with traditional methods.

GARNETS

These minerals are quite common in micaschists of the covers and also occur in orthoderivates. In tab. 8 microprobe analyses of garnets in granitoid gneisses and wet analyses of garnets in two micaschists (BRS 243 and BRS 323) of the covers are reported. The garnet formulas show a more or less complete saturation of the eight-coordinated sites suggesting the presence of a small Fe^{3+} content. Despite this conditioning, garnets in orthoderivates have a very constant composition and zoning is weak. They are formed by prevailing almandine-grossularite solid solutions and subordinately by spessartite and pyrope. The core is generally richer in almandine and pyrope while, rims have a higher grossularite content. For these minerals there are no obvious MgO/MgO + FeO tot. whole rock-garnet correlation ratios. Sample BRS 243 and BRS 323 respectively in an impure quartzites from the calcschists and in a Carboniferous (?) graphitic micaschist show a well defined compositional difference compared to garnet of orthogneisses. The first shows high spessartite contents while the second is very rich in almandine. This is essentially due to the particular composition of the rocks considered.

CALCITE - DOLOMITE GEOTHERMOMETER

An attempt to use the Calcite-Dolomite geothermometer in some samples from Jurassic calcschists and Triassic marbles has been made. Preliminary X-diffraction analyses and microscope observations allowed us to select samples in which crystals of the two minerals were present and in contact. Microprobe analyses were limited to cores of the minerals and the surface affected by the electronic pannel was limited to 20 $m\mu^2$. This geothermometer is essentially based on the original studies by HARKER and

TABLE 8 - Microprobe analyses of garnets

Samples	B R S 943 c)	B R S 943 r)	B R S 943 c')	B R S 943 r')	B R S 955 r)	B R S 955 c)	B R S 895 c)	B R S 895 r)	B R S 895 c')	B R S 776b c)	B R S 776b r)	BRS 243 +)	BRS 323 +)
SiO_2	37,50	37,80	37,70	37,50	37,60	38,00	37,00	38,00	37,80	37,50	37,70	36,51	36,30
TiO_2	—	—	—	—	—	—	—	—	—	—	—	0,63	1,00
Al_2O_3	21,34	22,13	21,14	21,76	21,17	21,19	21,04	21,19	21,08	20,85	20,98	22,96	21,53
Fe_2O_3	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0,67	0.10
Fe O	25,93	22,31	25,61	24,73	27,26	27,88	26,20	24,99	25,52	25,20	25,32	11,97	33,04
Mn O	4,88	5,40	5,52	4,07	0,61	1,55	3,27	2,36	3,35	3,05	2,81	14,36	1,63
Mg O	1,27	0,45	1,30	0,72	0,63	—	0,32	0,42	0,50	0,33	0,53	0,87	1,45
Ca O	9,06	12,45	8,73	11,22	12,73	13,38	12,16	13,03	11,74	11,46	12,65	12,04	4,95
Numbers of Ions on the Basis of 24 Oxygens													
Si	5,994	5,970	6,026	5,972	5,995	6,051	5,944	6,042	6,033	6,070	6,016	5,777	5,857
Al^{IV}	0,006	0,030	—	0,028	0,005	—	0,056	—	—	—	—	0,223	0,143
Al^{VI}	4,014	4,089	3,982	4,056	3,973	3,997	3,928	3,971	3,965	3,977	3,946	4,059	3,951
Fe^{3+}	—	—	—	—	—	—	—	—	—	—	—	0,080	0,012
Ti	—	—	—	—	—	—	—	—	—	—	—	0,075	0,121
Mg	0,303	0,106	0,310	0,171	0,150	—	0,077	0,100	0,119	0,080	0,126	0,205	0,349
Fe^{2+}	3,466	2,947	3,423	3,294	3,635	3,440	3,520	3,323	3,406	3,410	3,379	1,584	4,458
Mn	0,661	0,722	0,747	0,549	0,082	0,209	0,445	0,318	0,453	0,418	0,380	1,925	0,223
Ca	1,552	2,107	1,495	1,915	2,175	2,283	2,093	2,220	2,008	1,987	2,163	2,041	0,856
	5,982	5,882	5,975	5,929	6,040	5,932	6,135	5,961	5,986	5,905	6,048	5,755	5,886
mol. %													
Almandine	57,9	50,2	57,3	55,6	60,2	58,0	57,4	55,7	56,9	57,7	55,9	27,5	75,1
Spessartite	11,0	12,3	12,5	9,2	1,4	3,5	7,2	5,3	7,6	7,1	6,3	33,5	3,9
Pyrope	5,1	1,7	5,2	2,9	2,4	—	1,2	1,7	2,0	1,4	2,0	3,6	5,9
Andradite Grossularite	26,0	35,8	25,0	32,3	36,0	38,5	34,2	37,2	33,5	33,6	35,8	31,4	11,1

c) = core; r) = rim; +) = Samples analized with traditional methods.

Rocks: BRS 943 - Granodiorite gneiss; BRS 955 - Quartzdiorite gneiss; BRS 895a - Diorite gneiss; BRS 776b - Gabbrodiorite gneiss; BRS 243 - Carbonate quartzite; BRS 323 - Graphitic micaschist.

Analist: P. DA ROIT

TUTTLE (1955) for balancing the calcite-dolomite pair while varying temperature. It has recently been applied successfully (HOINKES, 1983; NESBITT and ESSENE, 1982) to the amphibolite field.

Equilibrium temperatures have been obtained by the formula by GRAF and GOLDSMITH (1958) and GOLDSMITH and NEWTON (1966).

$$\text{Log } X_{MgCO_3} = \frac{-1690}{T\ (K)} + 0{,}795$$

For the correction of molar percentages of magnesite, owing to the presence of Fe and Mn, we used the formula by TALANTSEV (1978). Mean analyses (x), standard deviations (δ), the molar percentage of calculated magnesite, extrapolated temperatures and mineral composition are reported in tab. 9.

Samples BRS 600 and BRS 697 were collected in the Southern part of the area (Val di Cesa and Forcella di Lappago) together with other samples (BRS 703 and BRS 535) from the near Western sector of the «Calcschists with ophiolites» complex. Triassic marbles (BRS 503 and BRS 692a) from the head of the Vizze Valley (Gries Scharte) to the North of the Gran Pilastro (Hochfeiler) have also been investigated. The temperatures obtained from the Calcschists samples in the Southern area indicate values near to 500° C, while those from the Western area (Fundres and Trens Valley) are lower.

A Triassic marble to the North gave the highest values (542° C). Another sample (BRS 503) from this area gave considerably lower values; this could depend on the presence of a widespread graphitic phase enveloping the carbonate granoblasts and which might have limited the diffusion of magnesium at this temperature equilibrium.

TABLE 9 - Composition of some calcites coexisting with dolomites

Samples	BRS 600		BRS 697		BRS 703		BRS 535		BRS 692a		BRS 503	
	$\bar{x}$ (20)	δ	$\bar{x}$ (22)	δ	$\bar{x}$ (30)	δ	$\bar{x}$ (20)	δ	$\bar{x}$ (30)	δ	$\bar{x}$ (20)	δ
CaO	53,73	0,43	53,53	0,69	54,07	0,95	54,16	0,65	53,28	1,00	53,49	1,33
MgO	1,68	0,35	1,49	0,67	1,35	0,26	1,21	0,56	1,92	0,89	1,41	0,99
FeO	0,34	0,04	0,71	0,34	0,32	0,06	0,38	0,27	0,41	0,29	0,67	0,25
MnO	0,03	0,05	0,11	0,20	0,09	0,07	0,04	0,23	0,05	0,24	0,39	0,29
CO_2^c	44,22		44,13		44,16		44,07		44,19		44,03	
T °C	511		496		478		464		542		497	
					mol.%							
$CaCO_3$	95,34		93,44		96,08		96,43		94,54		95,18	
$MgCO_3$	4,14		3,74		3,34		3,00		4,92		3,50	
$FeCO_3$	0,46		1,00		0,44		0,53		0,58		0,94	
$MnCO_3$	0,04		0,16		0,12		0,05		0,06		0,54	
$MgCO_3$	4,36		3,97		3,51		3,18		5,24		3,98	

Mineral paragenesis and location of the samples.
BRS 600 - Marble, Cc, Do, Mu, Mt (Cesa Valley); BRS 697 - Calcschist, Ab, Phg, Cc, Do (Lappago Saddle); BRS 703 - Marble, Cc, Do, Ab, Mu (Fundres Valley); BRS 535 - Marble, Cc, Do, Ab, Mu (Trens Pass); BRS 692a - Marble, Cc, Do (Gries Saddle-Vizze Valley); BRS 503 - Marble, Phg, Cc, Do (Gries Saddle-Vizze Valley).
Analist: P. DA ROIT

P-T CONDITIONS ON THE ALPINE METAMORPHIC EVENT

During the last decade, researches on the Hohe Tauern tectonic window metamorphites, seem to confirm the hypothesis that the Alpine metamorphic event is characterized by a HP-LT phase (SATIR, 1975; CLIFF *et al.*, 1977; MILLER, 1977; SELVERSTONE *et al.*, 1983) preceding the barrowian event in greenschist-amphibolites facies (SANDER's «Tauerkristallisation» - Lepontine event).

Studies carried out in experimental petrology, furthermore, have pointed out some isotherms (HOERNES and FRIEDRICHSEN, 1974) and isograds (ACKERMAND *et al.*, 1978; HOSCHEK, 1980-84), which outline the «thermic dome» in the tectonic window. The upper Neves Valley is mainly occupied by gneisses of granitic-granodioritic composition. This does not allow the development of a particular metamorphic paragenesis and therefore, calibration of the thermobarometric conditions, which occurred during the Alpine event, are not easily definable.

In spite of this, plagioclase, amphibole and garnet in the orthogneisses can furnish useful indications; quartz, K-feldspar and mica are generally associated.

Plagioclase usually shows a marked poikiloblastic texture with segregation of clinozoisite and, more rarely, white mica (*erfüllte Plagioklase*), which testifies to the arrangement of the original magmatic zoning.

In massive orthogneisses these segregation crystals are preferably arranged along the host's cleavages, while in more foliated types they also tend to be arranged along the «S» planes (see ANDREATTA, 1937).

In granite gneisses plagioclase cores have a 10-15% An content and an albitic rim. As more and more femic rocks are considered the An % plagioclase core reaches values of 30-40% while the albitic composition of the rims persists.

An content variations in plagioclase, which occur in orthogneisses of different composition can be explained as an incomplete transformation and re-equilibration of magmatic plagioclase during the metamorphic event. Many factors may have been responsible for the slowing down of the transformation, but this phenomenon was certainly mainly influenced by absence of particularly active dynamical phases, scarcity of fluids and rather low temperatures. These factors certainly hampered the ionic mobility essential for the transformation:

$$\text{Anortite} + H_2O \rightarrow \text{Albite} + \text{Zoisite}$$

It is likely, therefore, that the An content variations in plagioclase are not referable to two or three generations only, as shown by KARL (1950), MORTEANI and RAASE (1974) and PROSSER (1975).

Amphibole in orthoderivates consists of Mg- and tschermachitic-horneblende (see Fig. 13) and mainly occurs in metadiorites and metagabbros. Some elements (Mg and Fe) are clearly influenced by the whole rock composition (see Fig. 12) and, therefore, their content variations cannot assume a particular metamorphic meaning (SHIDO and MIYASHIRO, 1959; HIETANEN, 1974).

Other elements in the structural formulas such as Na, Al and Ti, seem to be correlatable with temperature and pressure (SHIDO and MIYASHIRO work cit.; BINNS, 1965; RAASE, 1974). According to the latter authors, furthermore, the Al^{VI} content rises with increasing temperature, while the Al^{IV} / Al^{VI} ratio can assume a barometric meaning. Using the diagrams proposed by LAIRD and ALBEE (1981), especially those relative to the $Al^{VI} + Fe^{3+} + Ti$ on Al^{IV} and to the Na^{M1} on $Al^{IV} + Fe^{3+} + Ti$, amphiboles

are mostly aligned along trends characterized by intermediate pressures (Dalradian-Scotish types). These results are also in agreement with those derived from the diagram proposed by RAASE (1974), which give thermal conditions near to 540° C and pressures of 4-6 Kb, thermobarometrical values which agree with those presumed in this area.

Occasionally green horneblende phenoblasts are surrounded by a late-kinematic phase of cummingtonite ([1]) which borders these megacrystals. A thin quartz granulation sharply separates these two monocline phases. In GOLE and KLEIN's opinion (1981), the appearance of cummingtonite (with grünerite optical features) associated with almandine, seems to indicate mean-high values of metamorphic grade which should correspond to slightly higher temperatures than those previously considered.

Garnet, occurring in many types of gneissic rocks, has a fairly uniform composition and a high almandine and grossularite molar content. The garnet present in the rare metapelites of the post-Hercynic covers has a markedly higher almandine molar content. Its diffusion and stability in these rocks together with the disappearance of chloritoid and clorite (relicts often embedded in the garnet itself) should indicate that the thermal conditions were at the boundary between the green-schists and amphibolite facies (cloritoid out). In regard to the «Calc-schists with ophiolites» complex, the typical association in this area is given by: Cc - Qz - Mu - Bi - Zo -Ab - Sph ([2]). In some marbles, the association Do -Cc - Phlo -Qz - Mu - Zo - Tr is also common. In HOSCHEK's opinion (1984), on the basis of the Bi -Zo - Cc association and of the appearance of pyrrhotite and pyrite in rocks which are poor or devoid of graphite, it is possible to deduce that, during the alpine metamorphic acme, the temperature was lower than 550° C, and that the pressure exceeded 4-6 Kb. On the other hand, the value of 5 Kb is also the lowest deducible from kyanite-staurolite-cloritoid associations in the Northern areas. A further confirmation of the temperature reached during Alpine metamorphism in the southern part of the Tauern window has been obtained by the calcite-dolomite geothermometer which provided values near 500° C. It is well known that the calcite-dolomite pair usually gives equilibrium temperatures slightly lower than other geothermometers.

According to DE VECCHI e PICCIRILLO (1968), in the Vizze and Fundres Valleys, the mineralogical associations in the ophiolites indicate thermobarometric conditions near 540-550° C and near 6-7 Kb (transition from quartz-albite-epidote-almandine greenschists subfacies to almandine amphibolite subfacies). Also in the ophiolites in the Neves Valley similar metamorphic conditions occur.

In conclusion, in this Alpine area the various metamorphic associations show conditions of equilibrium temperatures near 500° C and pressures which, at most, can reach 6 Kb. Evidences of a HP eo-Alpine event have not been found.

([1]) A mineral occurring in «Garbenschiefer» locally cropping out along the ridge Ponte di Ghiaccio and Cima della Pipa.

([2]) Cc = Calcite; Qz = quartz; Mu = white micas; Bi = biotite; Zo = zoisite; Ab = albite; Sph = sphene; Do = dolomite; Phlo = phlogopite; Tr = tremolite.

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