Two episodes of highgrade metamorphism in the Northern Bergell Alps

Two Episodes of Highgrade Metamorphism in the Northern Bergell Alps[1])

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With 6 figures and 1 table in the text

Abstract

Large deformed crystals of staurolite and kyanite which are partially replaced by sericite and chloritoid have been found in phyllites and micaschists of the Suretta nappe with an extensive distribution between Madesimo, Pizzo Stella, Piz dal Marc and Vicosoprano. This pre-kinematic metamorphic event, most likely Caledonian in age (GRÜNENFELDER et al. 1974), preceded the formation of staurolite, kyanite and sillimanite in the central part of the Bergell Alps which is attributed to the Miocene Lepontine metamorphism.

INTRODUCTION

A lot of effort has been devoted in recent years to the mapping of index minerals and metamorphic isograds have been outlined in the Central Alps. The interpretation of these mineral assemblages has generally been based on the assumption that the minerals crystallized after tectonic movements ended, during the Lepontine metamorphism. Thus it was surprising to find high-grade assemblages in the Pennine realm which obviously were products of a pre-Alpine episode, not, or only partially, affected by Alpine metamorphic activity.

The first find of macroscopic staurolite in greenschist territory – as far as Alpine metamorphic activity is concerned – has been at Alpe del Lago (Acqua Fraggia) in summer 1971. Figure 1 shows this large broken crystal of staurolite which was evidence for a multiphase metamorphic history in the Pennine nappes. It seems important enough to report it briefly in this volume dedicated

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[1]) Part 5 of: Geological observations in the Bergell Alps.

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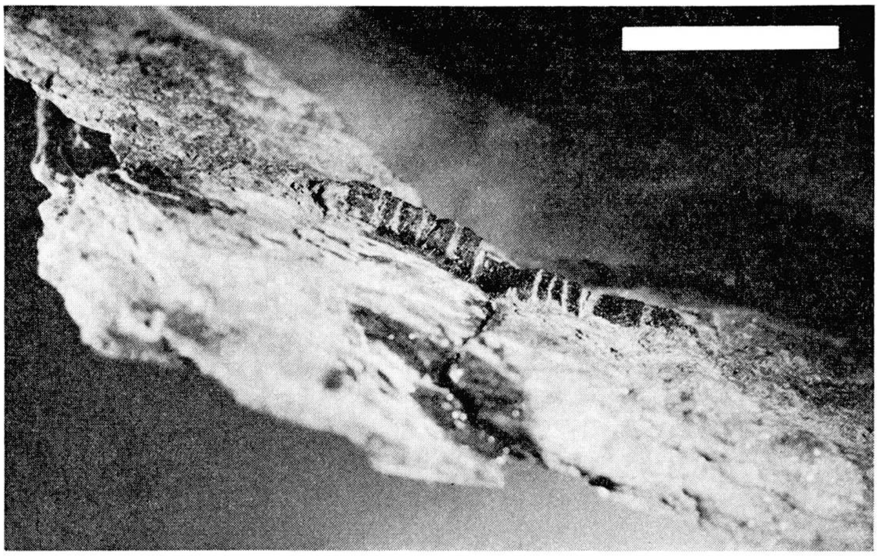


Fig. 1. A broken megacrystal of staurolite from Alpe del Lago (Acqua Fraggia). Sci 877. Bar is 2 cm long.

to Alpine metamorphism, since it adds to the examples of regional and contact metamorphism (e. g. Wenk et al. 1974) the topic of retrograde metamorphism.

Figure 2 shows a tectonic sketch of the Northern Bergell Alps in which finds of staurolite, kyanite and chloritoid – most of them identified in thin sections – are marked and table 1 lists the corresponding specimens. Staurolite and more rarely kyanite occur in the crystalline basal part of the Suretta nappe between Madesimo to the nortwest and Vicosoprano to the southeast.

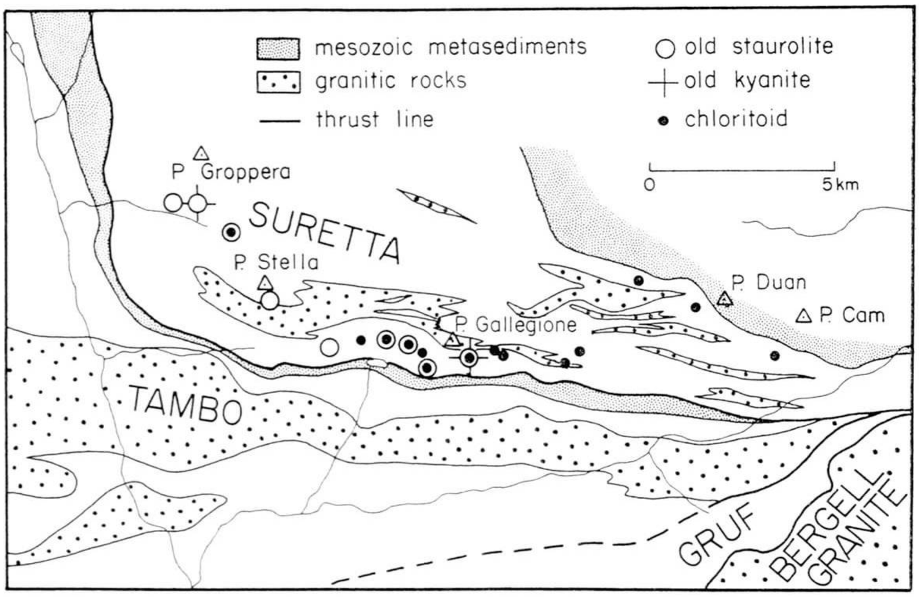


Fig. 2. Tectonic sketch of the Northern Bergell Alps. Finds of chloritoid, old staurolite and kyanite in the basal crystalline sequence of the Suretta nappe are indicated.

Table 1. *Mineral assemblages of rocks containing staurolite, kyanite or chloritoid in the crystalline base of the Suretta nappe, ordered from NW to SE*

O = handspecimen only (all others are thin section identifications), P = pseudomorph only. All speciment contain quartz

Specimen Number	Location	Coordinates (* = boulder)	Garnet	Kyanite	Staurolite	Chloritoid	Biotite	Muscovite	Pennine	Plagioclase (An content)	Accessories: Opaque	Accessories: Apatite	Accessories: Tourmaline	Remarks
Sci														
1171	Angeloga	750.1 /140.95	X		O		X	X	X	X	X			
1175		750.6 /140.8	X	X	X		X	X	X	25				
1177		751.25/140.4	X		X	X	X	X	X	25	X			
1183	Pizzo Stella	752.5 /138.5	X		O	X	X	X			X	X		
874	Acqua Fraggia	*755.05/136.22	X		X	X	X	X	X	0–10	X			
877		*755.8 /136.87	X		X	X	X	X	X	0–10	X			
878		755.5 /136.97	X			X		X	X	ab	X			
1166	S Cima di Lago	755.95/137.2	X		P	X		X	X		X			
1167		756.0 /137.25	X			X		X	X					clino-zoisite
1168		756.0 /137.3			O									large broken st
1160		756.7 /135.2			O									
1161	Passo Tur-bine	*756.75/136.2	X		P	X		X	X		X		X	
1162		*756.6 /136.35	X			X		X	X					
1058	NW Leira	*758.4 /136.1	X	X	X	X	X	X				X	X	
1022	Passo Prasgnola	758.76/136.91	X			X		X	X	ab	X		X	
1023	Passo Prasnola	758.75/136.9	X			X		X	X	ab	X		X	
1047	Drogh Grand	760.75/136.3	X		P	X		X	X		X	X	X	broken tourm.
1041	Cambun	761.2 /136.9	X			X		X	X	ab	X			sphene
1268	S Gletscher-horn	762.7 /138.95				X		X	X		X		X	graphite
1277	SW Piz Duan	764.3 /138.0				X			X	X	X	X		clino-zoisite
640	SE Piz Cam	767.7 /137.04	X			X		X	X		X	X		

STRATIGRAPHY AND STRUCTURE

Figure 3, a NS profile through the Pennine nappes in this area, illustrates the tectonic position of the Suretta nappe and the metamorphic zonation (see also WENK et al. 1974). An excellent and easily accessible section through Tambo and Suretta nappes is exposed between Piuro, Val Acqua Fraggia, Passo del Lago. Mte. Gruf to the south is in a zone of migmatites with cor

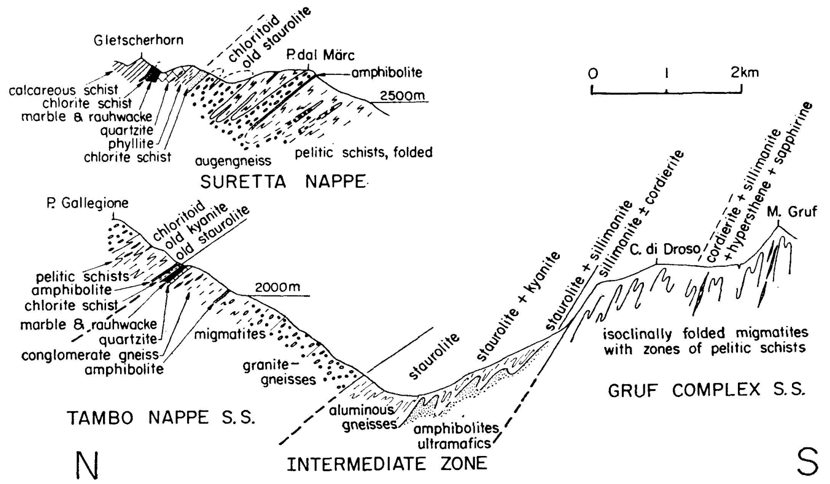


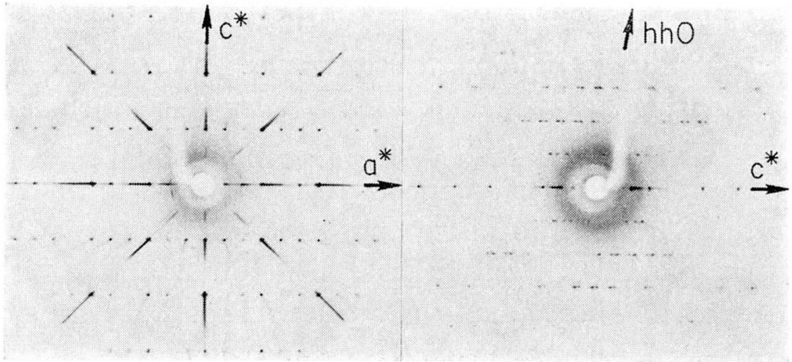
Fig. 3. NS cross-section from Pizzo Gallegione to Monte Gruf, indicating stratigraphy, tectonic units and metamorphic zonation.

dierite-sillimanite-hypersthene gneisses. Pizzo Gallegione to the north, only about 6 km apart in tectonic level is composed of chlorite-muscovite schists in greenschist facies. Isoclinally folded biotite-plagioclase-alkalifeldspargneisses of the Gruf complex ("Prata gneisses") contain locally inclusion zones of mafic, ultramafic, calcsilicate and pelitic rocks. The latter are characterized by sillimanite-cordierite assemblages. Pelitic rocks of the geosynclinal intermediate unit with amphibolites and olivinites resting on the northern limb of the Gruf anticlinorium display a metamorphic zonation from south to north into sillimanite, staurolite-kyanite-fibrolite and staurolite schists. The overlying massive sequence of predominantly megacrystic granite-gneisses – locally granitic in texture – belonging to the Tambo nappe sensu stricto is difficult to divide. Gneisses change into migmatites, but conspicuous index minerals are lacking even in aluminous layers. These crystalline rocks are covered by probably Permian conglomerate gneisses and a complicated Triassic sequence of quartzites, rauhwacke and limestones of considerable lateral variation which is attributed to heterogeneities in strain near the thrustplane between Tambo and Suretta nappe. The natural stratigraphic continuation with calcareous schists (schistes lustrés) is missing. Instead we find above the Triassic a thin band of amphibolite which can be traced over a wide area and on top a thick sequence of intensely folded micaschists, phyllites, occasionally augengneisses. Micaschists contain staurolite and kyanite and – especially in the higher parts – thin lenses of finegrained recrystallized muscovite aggregates. Phyllites are composed of muscovite, garnet and abundant chloritoid. The repetition of leucocratic augengneisses and aluminous schists is caused by large amplitude recumbent folds as is especially well visible in the excellently exposed glacial surfaces of Passo Bregalga, viewed from Piz Duan (top profile in figure 3). The latter area also displays the higher parts of the Suretta nappe. High grade metamorphic rocks change into phyllites, with layers of chlorite gneisses, and are covered by partially conglomeratic quartzites, rauhwacke and dolomitic limestones representing Triassic deposite (S Gletscherhorn). Triassic of the Suretta nappe is topped by the normal stratigraphic sequence of calcareous schists interbedded with chlorite gneisses ("prasinites"). The mineralogical composition with chlorite clinozoisite and albite points to green-schist facies but is non-distinctive. No chloritoid has been found in the mesozoic rocks. STAUB (1920) reported glaucophane (P. Duan, Pso. Furcela) but this could not be verified despite numerous collecting campaigns. Instead, large crystals of chloritoid with yellow-green-blue pleochroism – which could be mistaken for riebeckite – have been found in a "prasinite" layer (chlorite-clinozoisite-apatite-chloritoid schist) *below* the Triassic sequence along the crest between P. Duan and Pass da la Duana in the vicinity of STAUB's locality (Sci 1277, coord. 764.27/138.00, 2840 m). The optical properties of this chloritoid are different from chloritoid in the phyllites. Strong pleochroic colors and brown-blue interference colors are typical of this specimen.

The structure of the crystalline basal sequence of the Suretta nappe is by no means understood. Large amplitude recumbent folds produce a repetition of granitic and pelitic material. Foliations in schists and gneisses are parallel to the sedimentary bedding (Triassic) as well as to thrustplanes and conform with Alpine structures. Two systems of fold axes and lineations – one unique to the Suretta nappe, the second parallel to Alpine linear structures – are a reminder though that deformation occurred in more than one phase. Until more evidence is available it is impossible to decide whether deformation of these rocks, namely the conspicuous folding on all scales, is an Alpine or pre-Alpine feature. The 3 km-thick sequence of crystalline rocks in the Acqua Fraggia area decreases rapidly eastwards approaching the Bergell granite. The direct contact relations between Suretta nappe and Bergell granite are still open to debate (WENK, 1973). We presently favor a model in which Suretta elements form the Muretto anticline rather than the direct contact rocks of Monte del Forno - Monte Rosso.

METAMORPHISM

The discussion of the stratigraphy in figure 3 makes us aware that metamorphic isograds are strictly parallel to tectonic boundaries. Especially between Tambo and Suretta nappe there is a definite discontinuity in the metamorphic gradient. In this paper we are mainly concerned with mineral assemblages in the lower gneissic base of the Suretta nappe. Large crystals of staurolite are conspicuous and easily recognizable in the field. Sometimes tourmaline – a common component of the chlorite-muscovite schists which points to a sedi-



a b

Fig. 4. X-ray precession photographs; Mo-radiation.

a) Staurolite Sci 874, notice absence of asterism and of extra reflections 0kl, l = odd. 0kl-photograph.

b) Chloritoid Sci 878. Triclinic symmetry. Multiple twinning on (010).

mentary origin of these rocks (GOLDSCHMIDT and PETERS, 1932) – can be mistaken for staurolite and identification in thin-sections is necessary. The best specimens – resembling the Alpe Sponda crystals – have been collected along the old muletrail between Alpe Lago dentro (Piangesca) and Passo di Lei. Whenever staurolite is deformed, deformation was brittle as is documented by macro-crystals up to 10 cm long which are broken with offset pieces (figure 1). No asterism is observed in single crystal X-ray photographs (figure 4a). Precession photographs also display orthorhombic symmetry with no super-reflections (0kl, l=odd; DOLLASE and HOLLISTER, 1969) which is different from young staurolite in sillimanite bearing schists further south (WENK et al. 1974). In thin sections (figure 5a, b, c), it can be seen that staurolite, kyanite, and sometimes garnet are partially or completely replaced by chloritoid and sericite. In figure 5a a large staurolite-pseudomorph, now mostly sericite, contains still small relics of staurolite. Two micas, muscovite and some partially chloritized biotite are part of the original fabric. U-stage analysis of plagioclase shows that cores consist often of albite-oligoclase (An 10) with pure albite rims. This is different from the oligoclase-andesine composition in staurolite schists of Alpine age. Staurolite is partially replaced by long bladed crystals of chloritoid (figure 5b). Triclinic chloritoid, multiply twinned on (010) (figure 4b) is especially common in chlorite and tourmaline bearing garnet-muscovite phyllites but, as is evidenced by broken crystals, even the crystallization of chloritoid preceded at least the last stages of deformation (figure 5d).

These observations show that in the Bergell valley, in a section of 5 km, *the effects of Alpine metamorphism are visible as prograde metamorphism up to granulite facies to the south and as retrograde metamorphism of old amphibolite facies schists to the north.* Mineral assemblages in both terrains display a meta-

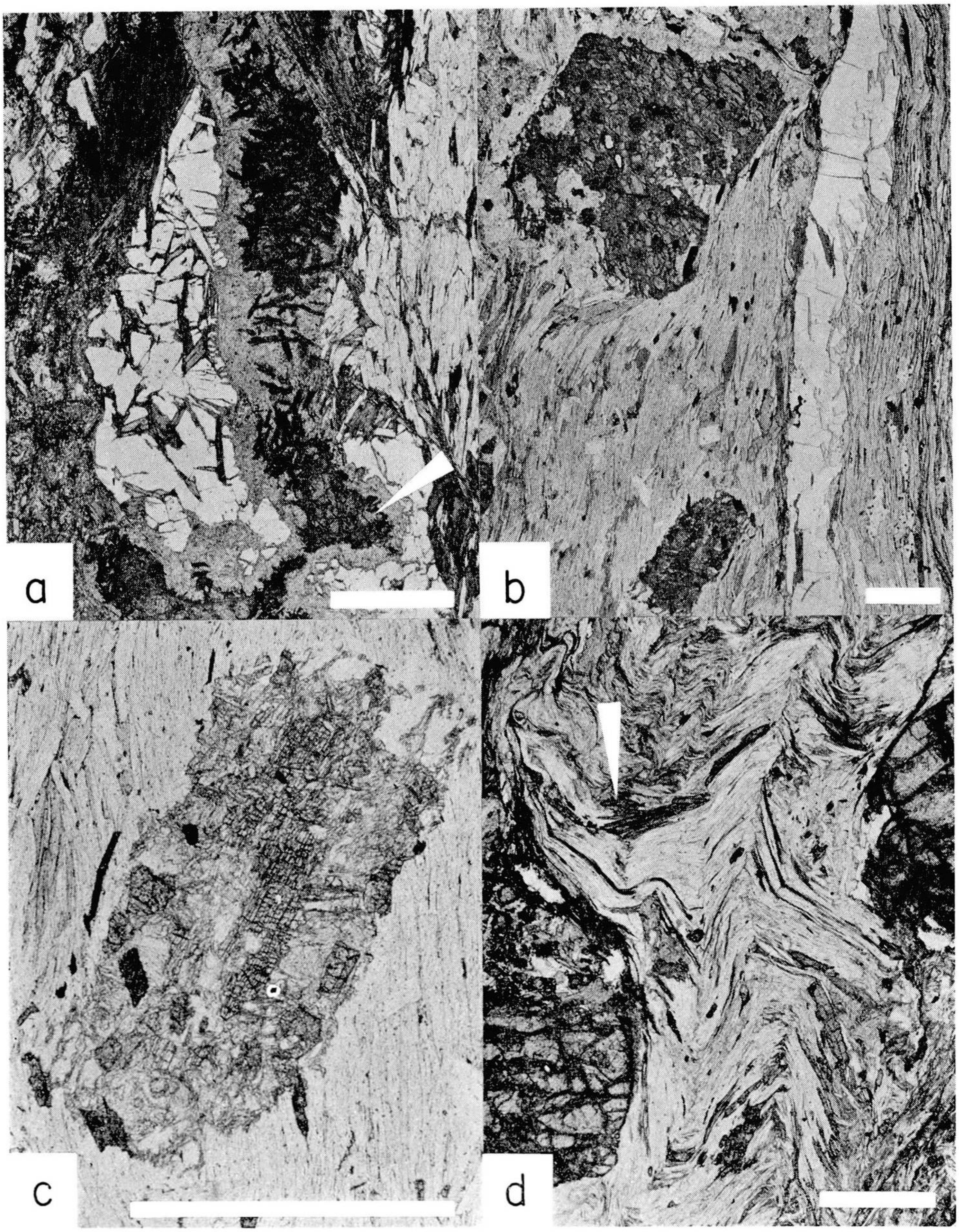


Fig. 5. Photomicrographs of selected specimens, plane polarized light. Bar is 1 mm.

a) Sci 874. Large grain of staurolite (gray, arrow), mostly replaced by chloritoid (dark bladed crystals) and sericite.
b) Sci 1158. Pseudomorph after staurolite now partially replaced by chloritoid and sericite in muscovite-chlorite schist.
c) Sci 1158. Pseudomorph after kyanite, partially replaced by sericite.
d) Sci 1123. Garnet-chloritoid-muscovite schist. Notice broken crystals of chloritoid (high relief, arrow) in kinks between garnet megacrysts.

morphic zonation. Retrograde effects decrease in intensity towards north. In the SE transformation is most advanced, garnets are recrystallized and biotite is converted completely to chlorite, all plagioclase is albite. Chlorite-schists and chloritoid phyllites are dominant rock types. Farther NW (Soglio-Gallegione) old garnet, rest of staurolite and kyanite are preserved. Plagioclase is oligoclase (An 10) with an albite rim. Chloritoid is very common. In the Madesimo-Pizzo Stella area, old biotite (with slight decrease in birefringence), garnet, staurolite, kyanite and oligoclase (An 25), still represent the old fabric; no chloritoid is present. But this regional pattern is less regular than in the prograde zone. There exist often heterogeneous zones of chlorite-chloritoid phyllites directly adjacent to staurolite-biotite schists. At this preliminary stage of investigation, we are unable to decide which ones of contributing factors, pressure-temperature regime, circulation of aqueous solutions or deformation were dominating the retrograde processes.

Becke (1909) discovered retrograde metamorphism in the Tauern. It is surprising that this phenomenon has largely been overlooked or rather avoided in the Central Alps which have become a classical area to study metamorphic zonation. The observation of old metamorphic schists, altered to phyllites also signifies that these rocks may compose larger parts of the Central Alps and that old mineral assemblages may still partially be preserved in many places. As has been pointed out already by Knopf (1934) medium grade metamorphism has little or no effect on the metamorphic mineral assemblage in pre-existing medium grade schists. In the Adamello contact zone, Justin-Visentin and Zanettin (1968) found it often difficult to distinguish between old and young staurolite, particularly since old staurolite seems to act as a nucleus for new crystals.

STAUROLITE IN THE CENTRAL ALPS

In evaluating the presence of staurolite in the Suretta nappe it is imperative to compare it with other occurrences in the Alps. These can be divided into Alpine and pre-Alpine (figure 6). Definitely pre-Alpine staurolite is found in units which have not been subjected to Alpine recrystallization such as the Southern Alps (Dervio, Val Gerola, Sotto Ceneri) or the higher Austro-Alpine nappes (Silvretta, Oetztal). On the other hand staurolite in mesozoic metasediments is definitely a Tertiary product. Such postmesozoic staurolite is reported from Lukmanier, Passo San Giacomo and Simplon. Most likely all staurolites in the Ticino – among them the megacrystals from the Alpe Sponda-Pizzo Forno – are products of the Lepontine metamorphism although evidence is not always conclusive. In particular, partially altered staurolite, kyanite and garnet crystals in the Tambo nappe between Chiavenna and Val Mesol-

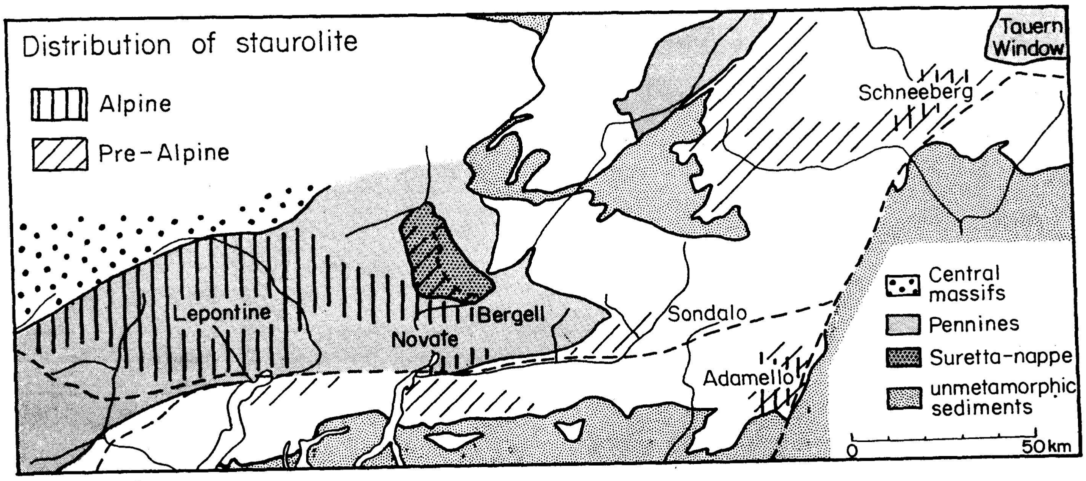


Fig. 6. Tectonic map of Central and Eastern Alps, indicating distribution of staurolite.

cina (WEBER, 1966) may represent relics of an older episode. JUSTIN-VISENTIN and ZANETTIN (1968) report young staurolite porphyroblasts in old staurolite-garnet-muscovite schists from the contact aureole of the Adamello intrusion (Val Breguzzo-Val Rendena). Old staurolite is partially replaced by sericite (and not by chloritoid as in the Bergell Alps), old garnet by chlorite. ZANETTIN and JUSTIN-VISENTIN (1971) found two generations of staurolite in pelitic schists of the "cristallino antico" of the Schneeberg complex (Alto Adige) and used this mineral to outline a zone of Tertiary recrystallization in Austroalpine terrain, west of the Tauern window.

Zircons of "old" staurolite bearing rocks have been dated with U/Pb methods and gave nonconcordant ages indicating that Precambrian material (~2000 m. y.) was subjected to Caledonian metamorphism (~430 m. y.) (GRAUERT et al. 1973) both in Southern Alps and Austroalpine nappes. The same age has recently been determined for the Suretta nappe (GRÜNENFELDER et al. 1974) and therefore formation of staurolite and kyanite is likely to be connected with this Caledonian event. Zircons in adjacent Tambo gneisses – on the other hand – document a Hercynian metamorphism (300 m. y.). Since there are no Hercynian imprints visible in Suretta rocks it is imperative that these two nappes were well separated and the distribution of "old" staurolite in figure 6 may outline the extent of Caledonian crystalline basement. If this is true, then it is surprising to see that this old regional metamorphism was of much wider importance than the rather local "domes"-some connected with presently exposed granitic intrusions – of Alpine age which are distributed along an east-west belt and are indicated on the map in figure 6. The presence of Caledonian metamorphic minerals in the Suretta nappe also suggests that the boundary between Tambo and Suretta nappe may be tectonically more important than between Pennine and Austroalpine nappes.

SUMMARY

Although this brief note, presenting the observation of "old" staurolite in the Suretta nappe, raises more questions than it answered, some conclusions can be drawn and some important problems which need further research can be specified.

— Retrograde metamorphism of greenschist grade left relics of preexisting mineral assemblages. Kyanite is the first mineral to be replaced by sericite. Staurolite is next and transforms to chloritoid and sericite. Clusters of chloritoid outline staurolite-pseudomorphs. Garnet is replaced last by chlorite. Accompanying is the alteration of biotite to chlorite and the albite rim forming around oligoclase. This new aspect of Alpine metamorphism introduces the Bergell Alps as an ideal area to study quantitatively both prograde and retrograde metamorphic reactions.

— There are indications that "old" staurolites are of Caledonian age. The young retrograde metamorphism with crystallization of chloritoid may be Alpine but most likely it was an early event preceding at least the final stages of deformation.

— Since the mineralogic and isotopic composition of Suretta crystalline rocks resembles closely rocks from the Southern Alps and the Austroalpine nappes, these tectonic units may be related. A detailed analysis of mineral assemblages, combined with further age determinations may permit to relate Suretta, Austroalpine and South Alpine "Caledonian" realms before the Alpine thrust movements and separate it from the Pennine realm sensu stricto, which shows strong imprints of Hercynian metamorphism.

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