# Age and degree of metamorphism of the Canavese Zone and of the sedimentary cover of the Sesia Zone

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# Age and Degree of Metamorphism of the Canavese Zone and of the Sedimentary Cover of the Sesia Zone

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With 2 figures, 2 photos, 2 tables and 1 plate

**Abstract**

44 samples from the Mesozoics of the Canavese Zone and the neighbouring South Alpine, as well as from the Tertiary volcanoclastic sedimentary cover of the Sesia Zone have been investigated by X-ray diffraction methods. 12 illite-rich samples were selected for K-Ar determinations with the following results:

(i) The Mesozoic sedimentary cover of the South Alpine domain is unmetamorphosed.

(ii) The metamorphic grade of the Canavese sediments s. str. reaches the transition anchizone-epizone. The age of the metamorphism in the Canavese s. str. ranges between 60 and 72 my, in other words belongs to the Eoalpine phase.

(iii) The Canavese between Biella and the Valle d'Ossola is epimetamorphic. The ages decrease from 38 my in the SW to 20 my in the NE and are interpreted as cooling ages of the Lepontine phase.

(iv) The Tertiary sedimentary cover of the Sesia Zone has been affected by a slight contact metamorphism (diagenesis-anchizone boundary) through the andesite effusives around 30 my ago.

**Riassunto**

Lungo la linea insubrica, in un'area compresa tra le Alpi centro-occidentali e il dominio sud-alpino, affiorano due importanti serie sedimentarie: i sedimenti del Canavese e la copertura terziaria vulcano-sedimentaria della zona Sesia-Lanzo. La tessitura e la struttura dei sedimenti mesozoici del Canavese s. s. («true» Canavese secondo STAUB e «Canavese *sensu stricto*» secondo NOVARESE) hanno fatto nascere il sospetto di una impronta metamorfica alpina; perciò si è ritenuto che i sedimenti del Canavese si prestassero bene allo studio degli effetti del metamorfismo sia eoalpino che della fase lepontina. Lo studio delle

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tufiti della copertura della zona Sesia-Lanzo è stato intrapreso nella prospettiva di indagare sulla evoluzione termica post-oligocenica della regione.

Mediante diffrazione ai raggi X, sono stati studiati 44 campioni provenienti dell'area citata: se ne è definita la paragenesi e il grado metamorfico utilizzando il parametro «cristallinità dell'illite» secondo KUBLER; inoltre dodici dei campioni studiati, particolarmente ricchi in illite, sono stati scelti per datazioni K-Ar. I risultati ottenuti sono qui di seguito riportati.

(i) I sedimenti del Canavese s.s. hanno subito un grado metamorfico di transizione tra l'anchizona e la epizona; l'età dell'evento metamorfico, compresa tra 60 e 72 milioni di anni, ci permette di attribuirlo alla fase eoalpina.

(ii) I sedimenti del Canavese, compresi tra Biella e la Valle d'Ossola, sono epimetamorfici; l'età, che variano tra 38 m.a. a SW e 20 m.a. a NE, sono interpretabili come età di raffreddamento della fase lepontina.

(iii) I sedimenti terziari che coprono la zona Sesia-Lanzo hanno subito un debole metamorfismo di contatto da parte delle colate andesitiche effuse circa 30 m.a. or sono senza per altro essere interessati da un metamorfismo regionale.

## Introduction

Along the Insubric Line, between the western Central Alps and the South Alpine domain, relics of two sedimentary series have been preserved: the sediments of the Canavese Zone and the volcano-detrital sedimentary cover of the Sesia Zone (see Plate I).

The present knowledge of Alpine metamorphism of this region was based on investigations on the polymetamorphic basement of the Sesia Zone (e.g. DAL PIAZ et al., 1972; HUNZIKER, 1974). In the course of this work it was noted that the texture and structure of the Mesozoic sediments of the Canavese s.str. indicated an Alpine metamorphic overprint. Therefore, the Canavese sediments seemed a good example on which to study the effects of the Eoalpine and Lepontine phases as prograde metamorphism. By the examination of the Tertiary tuffites it was hoped to reveal the post-Oligocene thermal history of the region.

## Geological setting

The Canavese Zone was introduced by ARGAND (1909) as a tectonic unit, intercalated between the Ivrea and Sesia Zones, containing strongly deformed crystalline schists, granites, Permian volcanic rocks and tuffites and Mesozoic sediments (see Fig. 1). Canavese sediments and South Alpine sediments have very similar facies. The above mentioned lithological sequence is only found between Lanzo and Biella. It is only here that the Canavese can clearly be characterized and therefore STAUB (1924) and NOVARESE (1929) defined this region as "true" Canavese and as "Canavese s.str.", respectively. In contrast to the Canavese s.str., the Canavese between Biella and Locarno can barely be

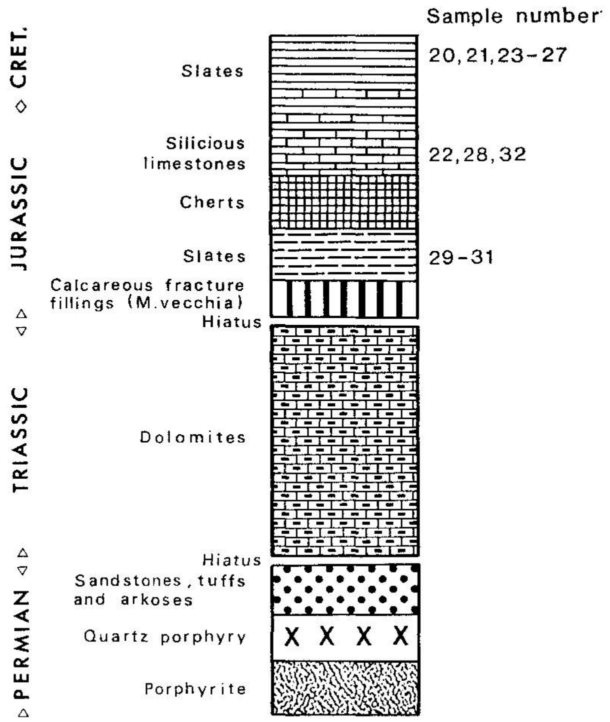


Fig. 1. Composite section of the Canavese s. str. after AHRENDT (1972, and unpublished data) with location of the samples. The basement of the Canavese sediments is formed by muscovite-chlorite-schists and Permian (?) granites. In some places the sediments are overthrusted on the meta-gabbros of the Ivrea Zone.

separated from the Sesia Zone. Here only the dolomites, marly and argillaceous schists of low-grade metamorphic origin can be interpreted with some certainty as Canavese Mesozoic[1]). Mylonites with feldspar porphyroclasts could be interpreted as Permian (?) meta-volcanics. Possible granites and mica schists can not be distinguished any more from the Sesia crystalline basement, because of Alpine metamorphism and deformation, and also because of the analogy between Sesia and South Alpine basement.

On the "Carta geologica d'Italia" 1 : 100,000 sheet Varallo (1927), Mesozoic Canavese sediments as well as calc-silicate marbles from the second Kinzigite-Diorite-Zone (for example A. Scarpiola near Rimella) and mylonitized crystalline basement of the Ivrea Zone (for example Folecchio near Balmuccia) have been marked with the signature $t^2$ and incorporated in the Canavese.

It has also often been mentioned that the so-called Scisti di Fobello e Rimella (signature Pt) are predominantly mylonitized crystalline basement of the Sesia Zone and do not belong to the Canavese (BERTOLANI, 1964; BAGGIO, 1966; PORADA, 1967; ISLER and ZINGG, 1974).

The andesites, tuffites and agglomerates exposed NW of Biella do not belong to the Canavese, but form the normal cover of the Sesia Zone (e.g. CARRARO, 1966; ELTER et al., 1966). This volcano-detrital series transgresses with a dis-

[1]) BERTOLANI (1964) and PORADA (1967) have interpreted the calcareous schists as strongly deformed and retrograded calc-silicate marbles. The same calcareous schists with identical mineralogy, however, are found together with Mesozoic dolomites and rauhwackes (REINHARDT, 1966).

cordance over the high pressure/low temperature metamorphic crystalline basement of the Sesia Zone. Components of this basement are found in the agglomerates and tuffites (e.g. GASTALDI, 1871; BIANCHI and DAL PIAZ, 1963). Because of stratigraphic and facies analogy to the Canavese and South Alpine, this series was thought to be of Permo-Carboniferous age. As a consequence this lead to the conclusion of a pre-Permo-Carboniferous age of the high pressure/low temperature metamorphism in the Sesia Zone. Recent investigations, however, have lead to contradictory interpretations. AHRENDT (1972), for example, observed that most of the andesites, tuffites and agglomerates were very little transformed and not deformed penetratively, in contrast to the Permian volcanics of the neighbouring Canavese Zone, and concluded that these volcanic rocks must be of Tertiary age. Radiometric data has yielded Eoalpine ages between 60 and 90 my for the high pressure/low temperature metamorphism of the Sesia Zone (DAL PIAZ et al., 1972; HUNZIKER, 1974). The same Eoalpine ages were found in the detrital micas of the tuffites (SCHEURING et al., 1974).

In addition HELLER and SCHMID (1974) found by means of palaeomagnetic investigations that the andesites yield pole positions similar to those obtained for the Oligocene plutons of Bergell, Biella and Traversella. These data are in good agreement with the palaeomagnetic work of AHRENDT et al. (in preparation) on the same rocks.

Last but not least, the andesites yielded K-Ar ages between 29 and 32 my (HUNZIKER, 1974; SCHEURING et al., 1974). All these facts lead to the conclusion of a Tertiary age for this volcano-detrital sequence, which can be regarded as a postorogenic sediment on top of Alpine metamorphic crystalline basement of the Sesia Zone.

On sheet Varallo (1927) two further volcanic exposures in the Sesia Zone are marked (with signature $\mu$). At least for the case of Montagne Ronda (NW Campello Monti) we are dealing with highly transformed and mylonitized intrusive rocks (meta-tonalites?) of the Sesia Zone, with amphibole porphyroclasts.

## Analytical methods

44 samples of Mesozoic and Tertiary sediments of the Canavese, the Southern Alps and the sedimentary cover of the Sesia Zone have been prepared according to FREY (1969), and measured with an X-ray diffractometer. The crystallinity of illite was determined in the fraction $< 2\,\mu$ according to KUBLER (1967). For the used parameters of our X-ray diffractometer, the non-metamorphic/anchimetamorphic boundary and the anchi-metamorphic/epi-metamorphic boundary correspond to a crystallinity index of 7.5 and 4.0, respectively.

For the K-Ar age determinations, the ground sample was decarbonatized in

5% acetic acid and the fraction $< 2\,\mu$ was then extracted through sedimentation in an Atterberg cylinder. This fraction was then dried at about 80° C and the K and Ar measured. K was determined on a Beckmann flame photometer, and Ar on a Varian GD 150 mass spectrometer. The spike comes from Clusius, Zürich, and is 99.98% $Ar^{38}$. The spike was calibrated against muscovite Brione M 4 Bern with a value of 6.31 $cm^3$ $Ar^{40}$ rad/g STP, and muscovite P 207 of the U.S.G.S. with a value of 28.15 $cm^3$ $Ar^{40}$ rad/g STP. A more detailed description is given in HUNZIKER (1974).

The decay constants used to calculate the ages were: $^{40}K\,\lambda_\beta = 4.72 \times 10^{-10}\,y^{-1}$ and $^{40}K\,\lambda_\epsilon = 0.585 \times 10^{-10}\,y^{-1}$ and the abundance of $K^{40}$ in $K = 1.19 \times 10^{-4}$moles/mole.

## Presentation and discussion of the data

The analytical data and the sample localities are listed in Table 1 and Table 2, and shown on Plate I. In addition, Fig. 1 shows the stratigraphic position of the samples of the Canavese s. str.

### THE SOUTH ALPINE SEDIMENTS

The South Alpine sediments contain illite, Fe-rich chlorite, kaolinite, smectite, a more or less regular mixed-layer chlorite/montmorillonite and an irregular mixed-layer illite/montmorillonite. The crystallinity of illite is, if at all measurable, greater than 10. The analyzed South Alpine sediments show no detectable influence of Alpine metamorphism.

### THE CANAVESE S. STR.

In the sediments of the Canavese between Lanzo and Biella illite and Fe-rich chlorite predominate, but subordinate amounts of a mixed-layer are also found. These small amounts do not allow an exact characterization, but a chlorite component is suspected. The crystallinity of illite varies between 3.0 and 6.2 reflecting conditions of the higher grade anchizone to epizone. The considerable variation found in crystallinity of illites here is due to the broad lithological spectrum of the analyzed samples ranging from marl through shale to chert in composition. In addition, the samples show strong differences in their degree of tectonic overprinting.

K-Ar age determinations on 5 illite-rich samples yielded Eoalpine ages between 60 and 71.8 my.

Table 1. *X-ray diffraction data*

| Zone | Sample No. | Lithology | Age | Fraction $<2\,\mu$: I | I+I/M | M | Chl | ML | other | Qz | Cc | Do | Ab | other | IK | Grade |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mesozoic and Cainozoic sediments, Southern Alps | 1 | clay parting in dolomite | Triassic | | >9 | | | | Kaol: <1 | × | × | × | | | 15.8 | unmetamorphosed |
| | 2 | clay parting in dolomite | Triassic | | >9 | | | | Kaol: <1 | × | | × | | | 10.8 | |
| | 3 | clay parting in dolomite | Triassic | | >9 | | | | Kaol: <1 | × | | × | | | 11.7 | |
| | 4 | calcareous slate | Lias | 4 | | 6 | | | | × | × | | | | – | |
| | 5 | calcareous slate | Lias | 3 | | 7 | | | | × | × | | | | – | |
| | 6 | argillaceous shale | Lias | | 10 | | | | | × | × | | | | 10.6 | |
| | 7 | argillaceous shale | Lias | 5 | | | | 5[1]) | | × | × | | | | – | |
| | 8 | argillaceous shale | Lias | 6 | | 3 | 1 | | | × | × | × | | | – | |
| | 9 | tuffite layer in Triassic dolomite | Triassic | 6 | | | | 3[1]) | Kaol: 1 | × | | × | | | – | |
| | 10 | argillaceous shale | Pliocene | 1 | | >8 | <1 | | | × | | | × | | – | |
| Mesozoic Sediments, Canavese Zone s.str. | 20 | argillaceous slate | L. Cretaceous | 6 | | | 4 | | | × | | | | Kf | 3.0 | epizone/anchizone |
| | 21 | argillaceous slate | L. Cretaceous | 9 | | | 1 | | | × | | | | | 5.8 | |
| | 22 | siliceous slate | Jurassic | 9 | | | | 1[2]) | | × | × | | | | 5.3 | |
| | 23 | argillaceous slate | L. Cretaceous | 8 | | | 2 | | | × | × | × | × | Bi | 4.2 | |
| | 24 | argillaceous slate | L. Cretaceous | 8 | | | 2 | | | × | | | × | | 5.6 | |
| | 25 | argillaceous slate | L. Cretaceous | 9 | | | 1 | | | × | | | | | 6.2 | |
| | 26 | argillaceous slate | L. Cretaceous | 8 | | | | 2[2]) | | × | | | | | 4.3 | |
| | 27 | argillaceous slate | L. Cretaceous | 8 | | | | 2[2]) | | × | | | | | 5.7 | |
| | 28 | siliceous slate | Jurassic | 9 | | | | 1[2]) | | × | | | | | 3.7 | |
| | 29 | argillaceous slate | Lias? | 7 | | | 3 | | | × | | | × | Bi | 3.3 | |
| | 30 | argillaceous slate | Lias? | 7 | | | 3 | | | × | × | | | Bi | 3.8 | |
| | 31 | argillaceous slate | Lias? | 8 | | | 2 | | | × | × | | | Bi | 4.1 | |
| | 32 | siliceous slate | Jurassic | 7 | | | 3 | | | × | × | | | | 3.9 | |

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mesozoic Sediments, Canavese Zone between Biella and the Valle d'Ossola | 40 | argillaceous slate from crushing zone | ? | 7 | | 1 | 2[1]) | | × | × | × | | | 4.0 | epizone |
| | 41 | metadolomite | Triassic | $<1$ | | 1 | $>6$[1]) | Tc: 2 | × | | × | × | | – | |
| | 42 | calc. schist | ? | 5 | | 5 | | | × | × | | | | 3.2 | |
| | 43 | calc. schist | ? | 9 | | 1 | | | × | × | × ? | | | 3.4 | |
| | 44 | calc. schist | ? | 4 | | 6 | | | × | × | | | | 2.8 | |
| | 45 | calc. schist | ? | 9 | | 1 | | | × | × | | | | 3.1 | |
| | 46 | calc. schist | ? | 9 | | 1 | | | × | × | | × ? | | 3.0 | |
| | 47 | argillaceous slate | ? | 7 | | 3 | | | × | | | | | 3.0 | |
| | 48 | calc. schist | ? | 7 | | 3 | | | × | × | | | | 3.0 | |
| | 49 | calc. schist | ? | 10 | | | | | × | × | | | | 3.9 | |
| | 50 | calc. schist | ? | 8 | | | | Pa: 2 | × | × | × | | | – | |
| | 51 | calc. schist | ? | 9 | | | | Pa: 1 | × | × | × | | | – | |
| | 52 | calc. schist | ? | 10 | | | | | × | × | × | | | 3.8 | |
| Tertiary volcano-detrital cover of the Sesia Zone | 60 | argillaceous shale | Oligocene | | 7 | 3 | | | × | | | | | 5 | See text |
| | 61 | argillaceous shale | Oligocene | 10 | | | | | × | | × | × | | 5.4 | |
| | 62 | argillaceous shale | Oligocene | 10 | | | | | × | | × | | | 7.4 | |
| | 63 | argillaceous shale | Oligocene | $>9$ | | $<1$ | | | × | | | | | 6.9 | |
| | 64 | argillaceous shale | Oligocene | 9 | | 1 | | | × | | × | × | | 6.2 | |
| | 65 | argillaceous shale | Oligocene | | 9 | 1 | | | | | | | | 5.2 | |
| | 66 | argillaceous shale | Oligocene | 6 | | 4 | | | × | | | × | | 4.6 | |
| | 67 | argillaceous shale | Oligocene | 10 | | | | | | | | | He | 3.9 | |

I: illite; I+I/M: illite with small amounts of irregular illite/montmorillonite mixed-layer; M: montmorillonite; Chl: chlorite; ML: mixed-layer; Kaol: kaolinite; Tc: talc; Pa: paragonite; Qz: quartz; Cc: calcite; Do: dolomite; Ab: albite; Kf: K-spar; Bi: biotite; He: hematite; IK: illite-crystallinity after KUBLER (1967).

1) ± regular chlorite/montmorillonite mixed-layer. 2) Undetermined mixed-layer, probably always with a chlorite component.

Table 2. *K-Ar age determination*

| Zone | Sample number | Lithology | Mineral | % K | % rad | cm³/g STP $^{40}$Ar rad. $10^{-6}$ | Age my |
|---|---|---|---|---|---|---|---|
| A | 23 | argillaceous slate | illite/chl. | 5.22 | 84.8 | 15.24 | 71.8±3.4 |
| A | 28 | siliceous slate | illite/ML | 3.76 | 88.6 | 9.06 | 60 ±2 |
| A | 29 | argillaceous schist | illite/chl. | 4.30 | 89.1 | 10.7 | 61.4±2.8 |
| A | 30 | argillaceous slate | illite/chl. | 4.16 | 84.4 | 11.33 | 67.1±3.2 |
| B | 40 | argillaceous slate | illite/chl. | 2.95 | 68.6 | 4.99 | 37.8±2.2 |
| B | 43 | calc. schist | illite/chl. | 4.48 | 32.7 | 5.20 | 29.1±3.6 |
| B | 45 | calc. schist | illite/chl. | 3.08 | 65.7 | 3.89 | 31.4±1.9 |
| B | 48 | calc. schist | illite/chl. | 4.15 | 44.6 | 4.63 | 27.8±2.5 |
| B | 49 | calc. schist | illite | 5.77 | 53.4 | 5.20 | 22.5±1.7 |
| B | 52 | calc. schist | illite | 3.80 | 21.4 | 2.97 | 19.5±3.7 |
| C | 60*) | detrital mica in tuffite | phengite | 8.28 | 94.0 | 25.56 | 76±4 |
| C | 61*) | detrital mica in tuffite | phengite | 7.92 | 87.4 | 24.49 | 76±4 |
| C | 63 | tuffite, fraction $<2\ \mu$ | illite/phengite | 5.46 | 76.4 | 8.19 | 37.2±1.9 |
| C | 67 | tuffite, fraction $<2\ \mu$ | illite | 6.29 | 78.1 | 7.80 | 30.8±1.6 |

Zone A = Canavese Zone s. str.
Zone B = Canavese Zone between Biella and the Valle d'Ossola
Zone C = Tertiary volcano-detrital cover of the Sesia Zone

*) Analysis from Scheuring et al., 1974.

## CANAVESE BETWEEN BIELLA AND THE VALLE D'OSSOLA

In this part of the Canavese Zone again well cristallized illite (illite crystallinity ≦ 4) and chlorite predominate. The occurrence of paragonite in the Valle d'Ossola is noteworthy. Regular chlorite/montmorillonite mixed-layer was only found in two samples: sample 40 comes from a shear zone and sample 41 is a massive talc-bearing dolomite. The presence of an expandable phyllosilicate together with talc is very uncommon. However, it has been described in other areas that expandable phyllosilicates disappear at higher metamorphic grade in carbonate rocks than in argillaceous rocks during prograde metamorphism (Wilson and Bain, 1970; Abbas, 1974). As the stability field of hydrous minerals is reduced in a $CO_2$-rich environment, this means that the mixed-layer in the dolomite must have an other composition than in the argillaceous rocks. The Canavese between Biella and the Valle d'Ossola has been affected by epizonal metamorphism with a possible exception of the neighbourhood of Biella where no suitable samples were available.

K-Ar age determinations on 6 illite-rich samples show Lepontic ages ranging from 38 my in the SW to 19.7 my towards the Lepontine area. Sampls 40 with 37.8 my comes from the outermost Lepontine sphere of influence and could possibly be a partially rejuvenated Eoalpine age. Nevertheless, in the neighbouring Sesia and Monte Rosa basement, the climax of the Lepontine phase around 36–40 my ago has been determined by means of various Rb-Sr mica ages (Hun-

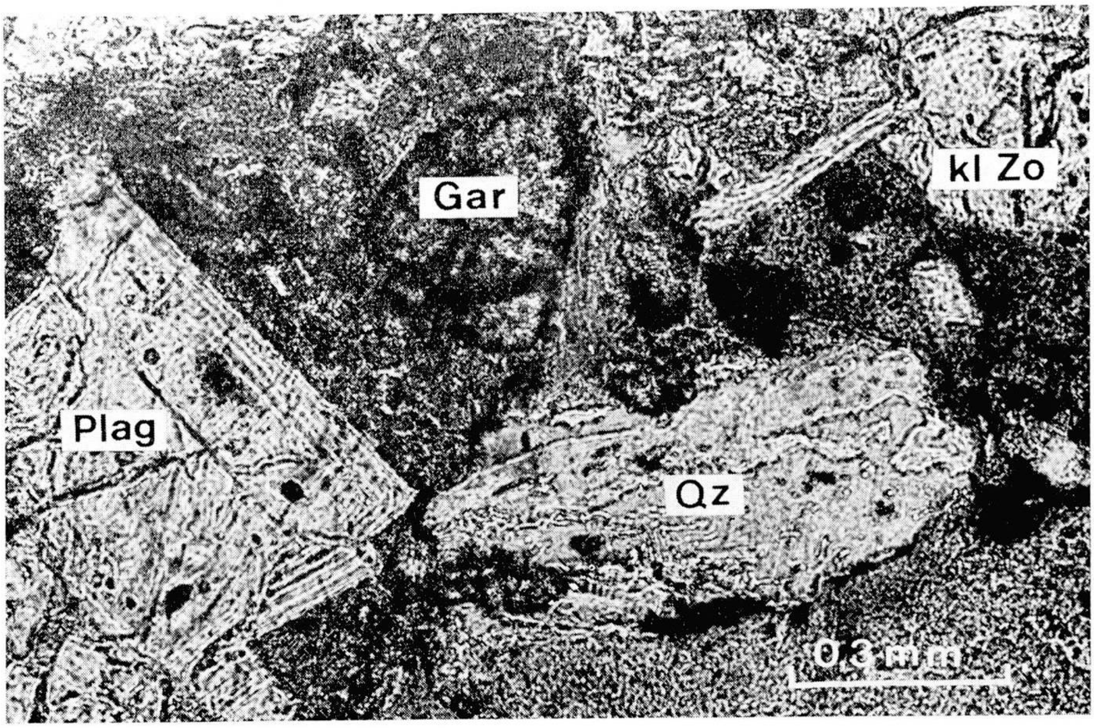


Photo 1. Tertiary tuffite with zoned plagioclase (An 36–60 Mol-%) from the andesite and garnet, clinozoisite and quartz from the high-p/low-T metamorphic basement of the Sesia Zone.

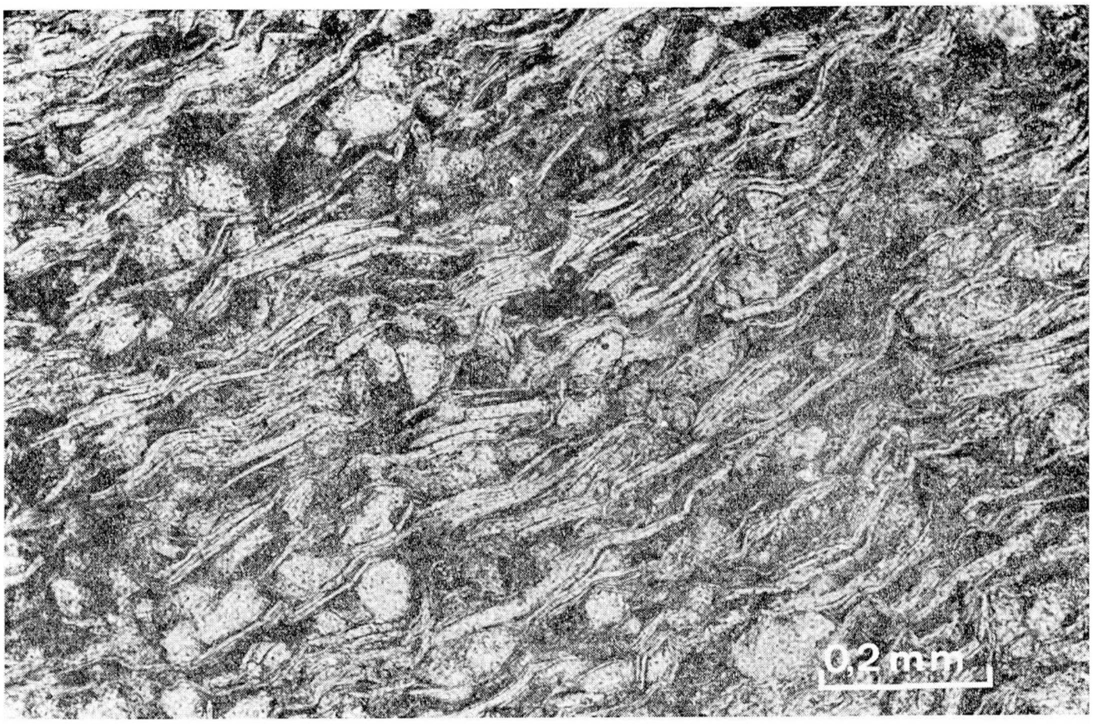


Photo 2. Fine grained part of the tuffite sequence with detrital phengite and quartz.

ZIKER, 1970, 1974), so that an analogous interpretation of the illite age of 37.8 my is most likely.

## TUFFITES OF THE TERTIARY SEDIMENTARY COVER OF THE SESIA ZONE

The Tertiary tuffites in part show a graded sequence with several cycles, starting with coarse psammitic beds and grading into argillaceous shale. Besides the andesitic volcano-clastic material the tuffites contain detritus of the "eclogitic micaschists" of the Sesia Zone, phengite of the modification 3T being particularly abundant (see Photo 1 and 2). The tuffite sequence is covered by an andesite flow of at least 40 m thickness at the locality of Falletti (N of Biella). These andesites are fresh with the exception of minor hydrothermal influences, as carbonate impregnation and the partial transformation of pyroxene to chlorite and celadonite.

The andesites have been dated on 5 samples, the ages of which range between 29 and 33 my (SCHEURING et al., 1974). In the $^{40}Ar/^{36}Ar$ diagram the data plot on a line with a normal intercept around 295 (Fig. 2a), in the $^{40}Ar/K$ diagram the points define a line with a zero intercept (Fig. 2b). This evidence suggests that a possible subsequent reheating of the andesites stayed below the laumontite facies, that is below the transition from diagenesis to the anchizone. Under laumontite facies conditions the andesites should have been rejuvenated according to our interpretation of the data of DELALOYE and SAWATZKI (1975) given on Fig. 2b. The data of these authors on andesite pebbles from the Eocene/Oligocene Taveyanne sandstone define a $^{40}Ar/K$ isochrone of 24 my which does not pass through the origin, therefore demonstrating Ar-loss due to a subsequent metamorphism in laumontite facies around 25 my ago (Fig. 2b).

Nevertheless the Tertiary tuffites of the Sesia cover have been affected by a slight metamorphism as can be shown with coal rank measurements (STADLER et al., 1976) and according to illite crystallinity data (this paper). As the tuffites have been deposited subaerially, both the syenite of Biella and the regional metamorphic Lepontine phase can be excluded as a heat source for this metamorphism. The only possible heat source remaining is the subsequent andesite flow itself. This contact metamorphism is documented by sample 67 with an illite crystallinity of 3.9 in the clay fraction giving an age of 31 my, i.e. the same age as the andesites.

As we were interested in regional metamorphism we did not sample a profile up to the contact of the andesite. Therefore, the following arguments are valid for samples collected about 3 m under the contact, that is, from the same locality as the samples we gave to STADLER and coworkers for coal rank measurements (op. cit., 1976). The upper temperature limit of this contact metamor-

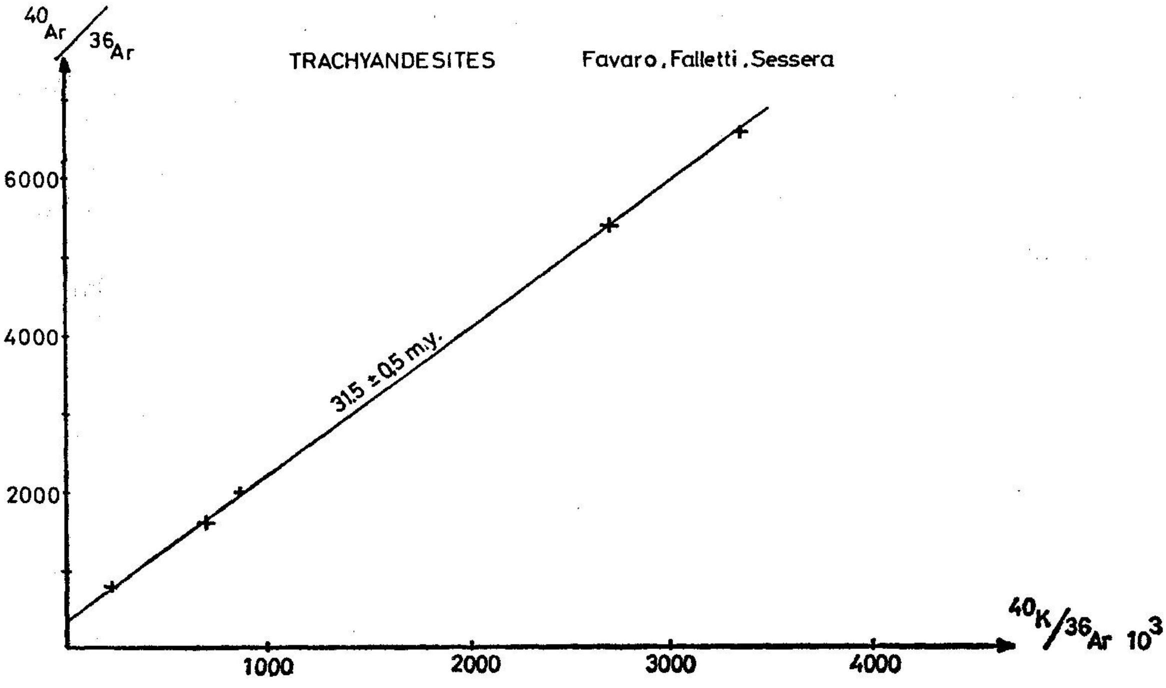


Fig. 2a.

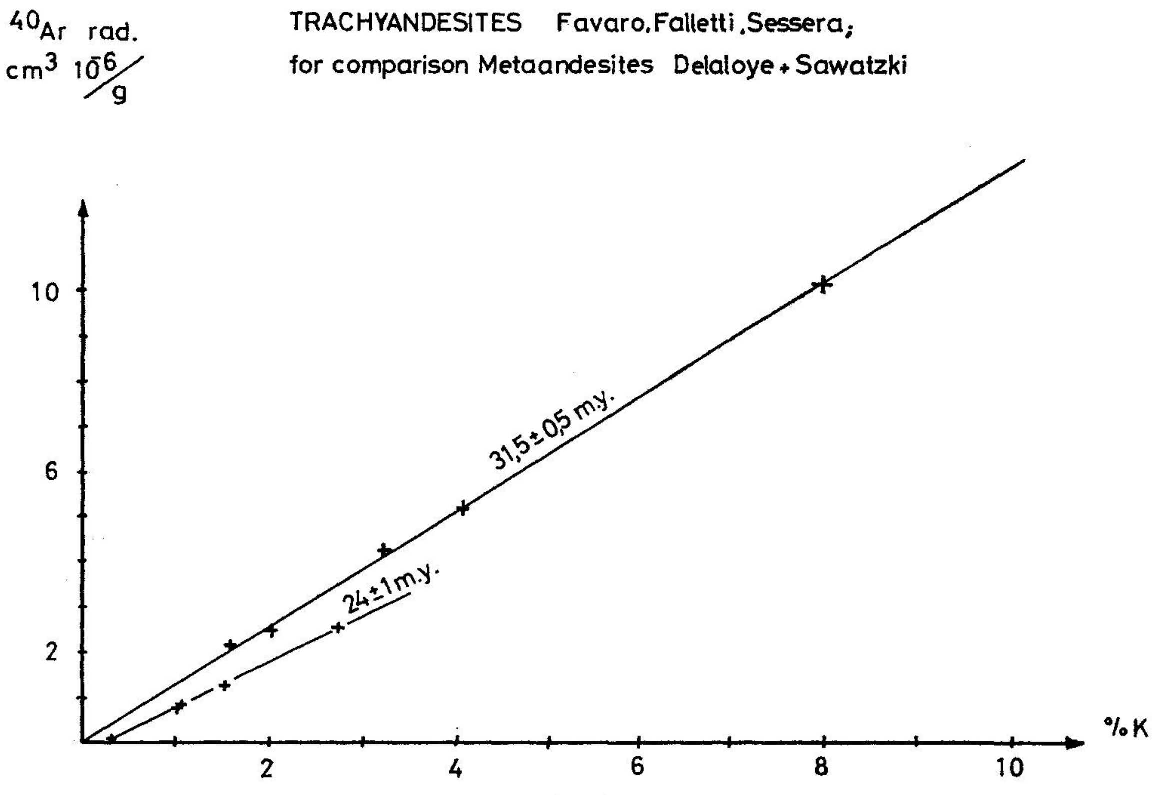


Fig. 2b.

Fig. 2. $^{40}Ar/^{36}Ar$ versus $^{40}K/^{36}Ar$ and $^{40}Ar/K$ plots of andesites from the volcano sedimentary cover of the Sesia Zone. The normal initial ratios of 295 in plot 2a and of 0 in plot 2b show that the andesites were not subjected to a thermal event subsequent to their deposition.

For comparison the data of Delaloye and Savatzki (1975) have been incorporated. These andesites have been affected by a metamorphism under laumontite facies conditions, the resulting rejuvenation of the K-Ar system is clearly shown by the isochron, not passing through the origin.

phism can be deduced from Eoalpine K-Ar ages of detrital phengites. Temperatures as high as 350° C would have rejuvenated these ages. The volcano-detrital basic plagioclase (An 36–60 mole per cent) was not albitized[2]). This fact implies conditions of diagenesis according to VOLL (1969) and conditions below the prehnite-pumpellyite facies according to COOMBS (1954)[3]).

The clay fraction of the tuffitic shales predominantly contain illite. Chlorite and illite with minor amounts of an irregular mixed-layer illite/montmorillonite are less frequent. The crystallinity of illite from 8 samples varies from 3.9 to 7.4 covering the whole range of the anchizone. These changes are probably due to the varying amount of detrital mica. The influence of the macroscopically detectable detrital mica can be shown with sample 63. The clay fraction of this sample gave an K-Ar age of 37 my, i.e. a mixed age between the 30 my old illites and the Eoalpine detrital phengite age. This implies that the measured illite crystallinities are too good because of the well crystallized detrital mica and therefore reflect metamorphic conditions higher than actually pertained. The crystallinity values around 7 might represent the true conditions, i.e. the boundary anchizone/diagenesis. This would confirm the observation that the detrital basic plagioclase was not albitized or that the prehnite-pumpellyite facies was not reached.

The plant remains of the tuffites have reached the rank of meta-anthracite to semi-graphite (STADLER et al., 1976). Correlating coal rank with mineral facies, for example, according to KISCH (1974), implies metamorphic conditions of the greenschist facies. According to WOLF (1975) this is only true for regional metamorphism; for contact metamorphism this coal rank would correspond to the lower grade anchizone.

Two further factors could explain the discrepancies between coal rank and metamorphic grade. Kinetics is more in favour of coalification than for the recrystallization of illite (e.g. KISCH, 1969, p. 409), giving differences, especially with short period heating. The second factor is stress favouring coalification (e.g. TEICHMÜLLER, 1975, Fig. 120). Deformation was in fact observed in the organic particles by STADLER et al. (1976) and is probably due to the tilting of the whole sedimentary series to their present steep dipping position (dip at the locality of Falletti: 105/60).

To summarize our observations we can say that the tuffites show a local and very low-grade metamorphism. Their sedimentary texture, characterized by graded bedding and floated detrital mica is conserved (Photo 2). We do not find any evidence for phyllitic slates with lepidoblastic texture, metamorphosed near the anchizone-epizone boundary as described by STADLER et al. (1976).

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[2]) Beside andesine to bytownite some albite is found in the tuffite. This albite, however, originates from the high pressure/low temperature assemblage of the neighbouring Sesia Zone just like the phengite, garnet, omphacite and glaucophane.

[3]) In the Permian volcanics of the Canavese s.str. we only found albite.

## Summary and conclusions

From the lithological point of view, the sediments of the Canavese s.str. are very similar to the South Alpine sediments, but in contrast to the latter, the Canavese sediments have been affected by Alpine deformation and metamorphism of anchi- to epizonal grade. K-Ar age determinations yield an Eoalpine age for this metamorphism. Across the Insubric Line, opposite the Canavese s.str., Eoalpine high pressure/low temperature metamorphism occurred contemporaneously. Thus the Insubric Line in this region separates two Eoalpine metamorphic facies domains of different pressure regimes.

The Canavese NE of Biella has been affected by the Lepontine phase of metamorphism in greenschist facies. The ages determined range between 38 and 19 my, dropping off towards the Lepontine area. The age of 38 my comes from the westernmost border of the Lepontine influence area, and could well date the climax of the Lepontine phase. The neighbouring basement of the Sesia Zone shows the same Lepontine overprint in greenschist facies and the same age pattern as the Canavese sediments.

The Tertiary sedimentary cover of the Sesia Zone has slightly been affected by contact metamorphism of the andesites. The correlation between petrographic data, coal rank, and illite crystallinity leads to an estimation of conditions of metamorphism at the diagenesis-anchizone boundary. This contact metamorphism around 30 my age is a local event.

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