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Data Article

Petrographic data from the Oligocene-lower Langhian succession of the Arquata Scrivia area in the Tertiary Piedmont Basin (NW Italy)

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A R T I C L E   I N F O

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A B S T R A C T

This petrographic database is a compilation made to study the Oligocene-Langhian succession of the Arquata Scrivia area, consisting of different shallow to deep-water marine sedimentary units deposited in the eastern Tertiary Piedmont Basin (NW Italy). This database is unique for the studied succession, which was not priorly investigated for the petrographic content of its component units.

The samples were collected from lower, middle and upper parts of each sedimentary unit and analyzed for identifying their petrographic composition via qualitative and quantitative methods by means of polarized-light microscope. The collected petrographic data are presented within quartz-feldspar-lithic ternary plots.

Even though these data are elementary analytical outputs, they represent the starting point for future analyses in order to understand the evolution of the basin on a larger scale.

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Specifications Table

Subject	Earth and Planetary Sciences, Geology
Specific subject area	Silicoclastic Sedimentary petrography
Type of data	Figures with descriptive text and tables
How the data were acquired	Data were acquired via sampling each stratigraphic unit at its base, mid- and top of its stratigraphic thickness by means of geological hammer. Thin sections were made at University of Milan Laboratory by following the recognized worldwide standard preparation. Each section was analyzed through a polarized-light binocular microscope (Leica DMLSP). Microphotographs were acquired by means of microscope camera (Zeiss, Axiocam 208 color). Past 4.09 (by University of Oslo) was used to organize and generate Ternary Plots for quantitative petrographic analyses. QGis version 3.10.4 (GNU software, public license) was used to organize and represent the dataset of the geological map of Fig. 1.
Data format	Raw (photos and petrographic data), analyzed and processed (ternary plots).
Description of data collection	Sandstone petrography qualitative and quantitative analyses along a section composed of deltaic to deep-water turbidite deposits
Data source location	Ref. System: UTM wgs84 32N X26a and X26b: 32T 490,077.3028E 4,943,626.293N X69: 32T 487,689.0589E 4,944,282.858N X61: 32T 486,999.2417E 4,944,877.845N X67: 32T 487,414.0593E 4,944,879.294N X81: 32T 491,380.9791E 4,945,469.355N X1: 32T 491,319.1794E 4,945,457.119N X2: 32T 491,306.1452E 4,945,471.674N X88: 32T 491,317.3727E 4,945,495.471N X89: 32T 491,284.8451E 4,945,527.238N X90: 32T 491,269.8129E 4,945,560.056N X25: 32T 486,625.1742E 4,945,613.689N X34a and X34b: 32T 491,507.8657E 4,946,386.938N X37: 32T 489,808.7508E 4,945,263.902N X36: 32T 491,143.0349E 4,946,048.55N X39: 32T 488,198.0182E 4,945,155.091N X101: 32T 491,149.9224E 4,946,565.579N X102: 32T 488,879.0504E 4,945,447.022N X104: 32T 489,034.8312E 4,945,461.387N X30: 32T 489,497.6497E 4,946,026.43N X107a: 32T 488,182.8252E 4,947,584.06N
Data accessibility	Repository name: Petrographic data from the Oligocene-lower Langhian succession of the Arquata Scrivia area in the Tertiary Piedmont Basin (NW Italy) Data identification number: 10.5281/zenodo.6855958 Direct URL to data: https://doi.org/10.5281/zenodo.6855958

Value of the Data

- These data are useful because they represent new petrographic analyses from an area which has never previously investigated, located in the eastern part of the Tertiary Piedmont Basin.
- These data can be helpful to reconstruct the sedimentary evolution and the patterns of sediment dispersion within the Tertiary Piedmont Basin, in a strategic area to understand the complex evolution between Alps and Apennines.
- These data, compared with data collected in other portions of the Tertiary Piedmont Basin, can be utilized to investigate the variability of the petrographic signature within the basin.

Objective

This dataset is realised in order to gather newly petrographic data from poorly studied sedimentary succession cropping out in the western part of the north-eastern Tertiary Piedmont Basin. These data are shared to be available for a further availment.

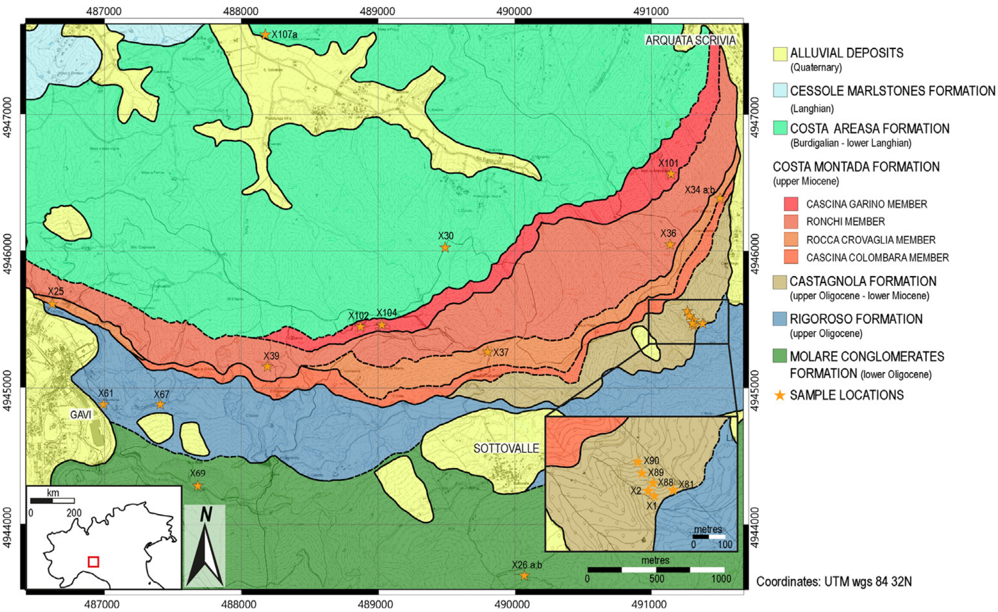


Fig. 1. Synthetic geological map with the location of the petrographic samples in the Arquata Scrivia area (Tertiary Piedmont Basin, NW Italy). The lithostratigraphic classification is based on Ghibaudo et al. [1] work.

1. Data Description

1.1. Petrographic Data

This petrographic description classifies samples from the Arquata Scrivia succession (Fig. 1, Oligocene-Langhian, [1]) of the Tertiary Piedmont Basin (NW Italy). These rock samples come from medium/fine-grained sandstones which do not show any significant evidence of recent meteoric diagenesis. The studied units were sampled in their base, middle and upper portions (where possible 2 samples per site were acquired) in order to have an overview of the petrographic signature from the bottom to the top of each stratigraphic unit. Samples are distributed within the units as follow:

Lower part of the succession (lower Oligocene-lower Miocene):

- Molare Conglomerates – cf. ‘Conglomerati di Savignone and Arenarie di Ranzano’ of [2,3], ‘Conglomerati della Val-Borbera’ of [4,5], ‘unità Molare-Borbera’ of [6]): X26a, X26b, and X69
- Rigoroso Marlstones – cf. ‘Marne di Rigoroso’ of [3,X3]; ‘unità Gremiasco’ of [7]; ‘Gremiasco Turbidite System’ of [8]: X61 and X67
- Castagnola Formation – cf. “Formazione di Castagnola” [9]; ‘Membro di Costa Montanda’ of [1]: X81, X1, X2, X88, X89, X90

Upper part of the succession (lower Miocene-lower Langhian):

- Costa Montada Formation – it includes ‘Membro di Cascina Colombara’, ‘Membro di Rocca Crovaglia’, ‘Membro di Ronchi’, and ‘membro di Cascina Garino’ of [1]: X34a, X34b, X25, X37, X36, X39, X101, X104, X102
- Costa Areasa Formation – cf. ‘Formazione di Cortemilia’ of [10]: X30, X107

1.2. Qualitative Petrographic Analysis of Samples

In the following lines, qualitative description of samples is reported associated to an example of most common clastic components collected in a microphotograph plate (Fig. 2)

1.3. Sample X26a

This sample was taken in the middle part of the Molare Conglomerates (coord. 32T 490,077.3028E 4,943,626.293N) from a normally graded coarse- to very fine-grained sandstone bed.

In the thin section, the rock has a clast-supported, moderately sorted, texture made of clasts ranging from very-fine to coarse-grained sandstone. The clastic fraction is composed of angular (low-sphericity) lithic fragments, sub-angular to sub-rounded (low-sphericity) feldspar fragments, and sub-angular to rounded (high-sphericity) quartz clasts. Polycrystalline metamorphic clasts (rich in quartz, feldspars, and micas), serpentineschists and serpentinites are recognised as lithic fragments. Quartz clasts are either monocrystalline or polycrystalline. Accessory grains include well rounded (high-sphericity) glauconite, monocrystalline detrital micas, chlorite (either as replacement of feldspars or monocrystalline), unclassified opaque minerals, and carbonate mudstones-wackestones.

Linear, point, concavo-convex, and sutured contacts are recognised among clasts. The intraclasts porosity is occupied by either equant or microcrystalline calcite cement and, subordinately by fine carbonate matrix. The estimated porosity value is qualitatively lower than 5% of the total thin section surface and it is mainly intragranular.

1.4. Sample X26b

This sample was taken in the middle part of the Molare Conglomerates (coord. 32T 490,077.3028E 4,943,626.293N) from a normally graded very coarse- to very fine-grained sandstone bed.

In the thin section, the rock has a clast-supported, moderately sorted, texture made of clasts ranging from fine to medium/coarse-grained sandstone. The clastic fraction is composed of subrounded to rounded (high-sphericity) quartz clasts, sub-angular to sub-rounded (low-sphericity) feldspar clasts, and sub-angular to sub-rounded (low-sphericity) lithics fragments. Quartz clasts are either polycrystalline or monocrystalline. Polycrystalline metamorphic clasts (rich in quartz, feldspars, and micas), serpentineschists and serpentinites are recognised as lithic fragments.

Accessory grains include monocrystalline detrital micas, chlorite (either as replacement of feldspars or monocrystalline), unclassified opaque minerals, and carbonate mudstones-wackestones.

Linear, point, concavo-convex and sutured contacts are recognised among clasts. The intraclasts porosity is occupied by either equant or microcrystalline calcite cement and, subordinately by fine carbonate matrix. The estimated porosity value is qualitatively lower than 5% of the total thin section surface and it is mainly intragranular.

1.5. Sample X69

This sample was taken close to the top of the Molare Conglomerates (coord. 32T 487,689.0589E 4,944,282.858N) from a normally graded very coarse- to very fine-grained sandstone bed.

In the thin section, the rock has a clast-supported, moderately sorted, texture made of clasts ranging from fine to medium/coarse-grained sandstone. The clastic fraction is composed of subangular to rounded (high-sphericity) quartz clasts, sub-angular to sub-rounded (low-sphericity)

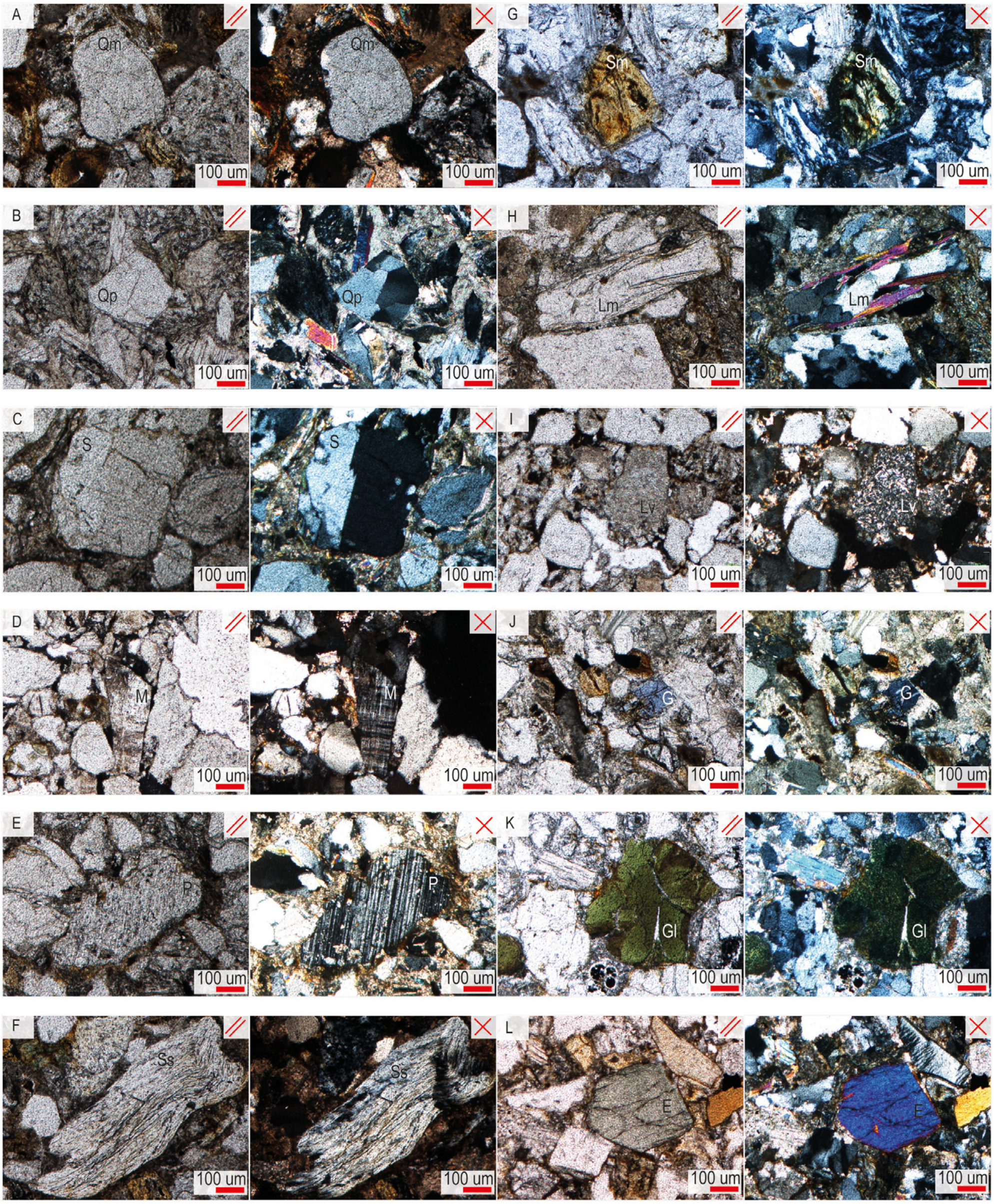


Fig. 2. Microphotographs of the analyzed samples. (A) Qm: Monocrystalline quartz (sample X37, Costa Montada Formation, Rocca Crovaglia Member); (B) Qp: Policrystalline quartz (sample X61, Rigoroso Formation); (C) S: Sanidine (sample X107a, Costa Areasa Formation); (D) M: Microcline (sample X81, Castagnola Formation); (E) P: Plagioclase (sample X107a, Costa Areasa Formation); (F) Ss: Serpentineschists (sample X37, Costa Montada Formation, Rocca Crovaglia Member); (G) Sm: Massive serpentinite (sample X37, Costa Montada Formation, Rocca Crovaglia Member); (H) Lm: Metamorphic lithic (sample X2, Castagnola Formation); (I) Lv: Volcanic lithic (sample X81, Castagnola Formation); (J) G:Glaucophane (X34b, Costa Montada Formation, Rocca Crovaglia Member); (K) Gl: Glauconite (sample X107a, Costa Areasa Formation); (L) E: Epidote-group mineral (sample X90, Castagnola Formation).

feldspar clasts, and sub-angular to sub-rounded (low-sphericity) lithics fragments. Quartz clasts are either polycrystalline or monocrystalline. Serpentineschists, serpentinites, and polycrystalline metamorphic clasts (rich in quartz, feldspars, pyrossens, and micas) are recognised as lithic fragments.

Accessory grains include well rounded glauconite clasts, glaucophane, monocrystalline detrital micas, monocrystalline chlorite, monocrystalline pyrossens and unclassified opaque minerals.

Linear, concavo-convex and point contacts are recognised among clasts. The intraclasts porosity is occupied by microcrystalline calcite cement and, subordinately by fine carbonate matrix. The estimated porosity value is qualitatively lower than 5% of the total thin section surface and it is mainly intergranular.

1.6. Sample X61

This sample was taken close to the base of the Rigoroso Marlstones (coord. 32T 486,999.2417E 4,944,877.845N) from a very coarse- to very fine-grained sandstone bed.

In the thin section, the rock has a clast-supported, poorly sorted, texture made of clasts ranging from very fine to very coarse-grained sandstone. The clastic fraction is composed of sub-angular to rounded (high-sphericity) quartz clasts, sub-angular to sub-rounded (low-sphericity) feldspar clasts, and sub-angular to sub-rounded (low-sphericity) lithics fragments. Quartz clasts are either polycrystalline or monocrystalline. Serpentineschists, serpentinites, fine-grained volcanics, and polycrystalline metamorphic clasts (rich in quartz, feldspars, pyrossens, and micas) are recognised as lithic fragments.

Accessory grains include well rounded glauconite clasts, monocrystalline chlorite, monocrystalline detrital micas, glaucophane and opaque minerales. Linear, concavo-convex and point contacts are recognised among clasts. The intraclasts porosity is occupied by either equant or, subordinately, microcrystalline calcite cements. The estimated porosity value is qualitatively lower than 5% of the total thin section surface and it is mainly intergranular.

1.7. Sample X67

This sample was taken close to the base of the Rigoroso Marlstones (coord. 32T 487,414.0593E 4,944,879.294N) from a coarse- to very fine-grained sandstone bed.

In the thin section, the rock has a clast-supported, moderately sorted, texture made of clasts ranging from fine to medium/coarse-grained sandstone. The clastic fraction is composed of sub-angular to rounded (high-sphericity) quartz clasts, sub-angular to sub-rounded (low-sphericity) feldspar clasts, and sub-angular to sub-rounded (low-sphericity) lithics fragments. Polycrystalline metamorphic clasts (rich in quartz, feldspars, and micas), serpentineschists, serpentinites and coarse-grained igneous rocks are recognised as lithic fragments. Quartz clasts are either polycrystalline or monocrystalline.

Accessory grains include well rounded glauconite clasts, monocrystalline chlorite, monocrystalline detrital micas, and glaucophane clasts and unclassified opaque minerals. Linear, point and concavo-convex contacts are recognised among clasts. The intraclasts porosity is occupied by either equant or, subordinately, microcrystalline calcite cements. The estimated porosity value is qualitatively lower than 5% of the total thin section surface and it is mainly intergranular.

1.8. Sample X81

This sample was taken close to the base of the Castagnola Fm. (coord. 32T 491,380.9791E 4,945,469.355N) from a normally graded coarse- to very fine-grained sandstone bed.

In the thin section, the rock has a clast-supported, very well sorted, texture made of medium-grained sandstone clasts. The clastic fraction is composed of sub-angular to sub-rounded (high-sphericity) quartz clasts, angular to sub-rounded (low-sphericity) feldspar clasts, and angular to sub-rounded (low-sphericity) lithic fragments. Polycrystalline metamorphic clasts (rich in quartz, feldspars, and micas), serpentineschists, serpentinites, fine- and coarse-grained igneous rocks are recognised as lithic fragments. Quartz clasts are either monocrystalline or polycrystalline.

Accessory grains include well rounded glauconite clasts, monocrystalline detrital micas and monocrystalline chlorite, carbonate mudstones-wackestones, bioclasts and unclassified opaque minerals.

Linear, point, concavo-convex and sutured contacts are recognised among clasts. The intra-clasts porosity is occupied by either equant or microcrystalline calcite cements and, subordinately, by ematite cement. The estimated porosity value is qualitatively lower than 5% of the total thin section surface and it is mainly intergranular.

1.9. Sample X1

This sample was taken close to the base of the Castagnola Fm. (coord. 32T 491,319.1794E 4,945,457.119N) from a ca. 1.5 m-thick, normally graded coarse- to very fine-grained, strongly cemented, sandstone bed (i.e., k-bed #1).

In the thin section, the rock has a clast-supported, moderately sorted, texture made of clasts ranging from medium- to coarse-grained sandstone. The clastic fraction is composed of sub-angular to sub-rounded (low-sphericity) feldspar clasts, sub-angular to sub-rounded (high-sphericity) quartz clasts, and angular to sub-rounded (low-sphericity) lithic fragments. Quartz clasts are chiefly monocrystalline, even though polycrystalline clasts subordinately occur. Polycrystalline metamorphic clasts (rich in quartz, feldspars, and micas), fine-grained volcanics, and serpentineschists are recognised as lithic fragments. Accessory grains include carbonate mudstones-wackestones, unclassified opaque minerals, and bioclasts.

Linear, point, concavo-convex and sutured contacts are recognised among clasts. The intra-clasts porosity is occupied by either equant calcite or microcrystalline calcite cements. The estimated porosity value is qualitatively lower than 5% of the total thin section surface and it is mainly intragranular.

1.10. Sample X2

This sample was taken close to the base of the Castagnola Fm. (coord. 32T 491,306.1452E 4,945,471.674N) from a ca. 1.5 m-thick, normally graded coarse- to very fine-grained, strongly cemented, sandstone bed (i.e., k-bed #1).

In the thin section, the rock has a clast-supported, moderately sorted, texture made of clasts ranging from fine- to medium/coarse-grained sandstone. The clastic fraction is composed of sub-angular to sub-rounded (low-sphericity) feldspar clasts, sub-angular to sub-rounded (high-sphericity) quartz clasts, and angular to sub-rounded (low-sphericity) lithic fragments. Quartz clasts are chiefly polycrystalline, even though monocrystalline clasts subordinately occur. Polycrystalline metamorphic clasts (rich in quartz, feldspars, and micas), fine-grained volcanics, serpentineschists, and serpentinites are recognised as lithic fragments. Accessory grains include monocrystalline detrital micas, chlorite clasts, glaucophane, carbonate mudstones-wackestones, unclassified opaque minerals, and bioclasts.

Linear, point and concavo-convex contacts are recognised among clasts. The intraclasts porosity is occupied by either equant or microcrystalline calcite and ematite cements. The estimated porosity value is qualitatively lower than 5% of the total thin section surface and it is mainly intragranular.

1.11. Sample X88

This sample was taken in the middle part of the Castagnola Fm. (coord. 32T 491,317.3727E 4,945,495.471N) from a normally graded coarse- to very fine-grained sandstone bed.

In the thin section, the rock has a clast-supported, well sorted, texture made of clasts ranging from fine- to medium/coarse-grained sandstone. The clastic fraction is composed of angular to sub-rounded (low-sphericity) feldspar clasts, sub-angular to rounded (high-sphericity) quartz clasts, and angular to sub-rounded (low-sphericity) lithic fragments. Quartz clasts are chiefly monocrystalline, even though polycrystalline clasts subordinately occur. Polycrystalline metamorphic clasts (rich in quartz, feldspars, and micas), fine-grained volcanics, serpentineschists, and serpentinites are recognised as lithic fragments. Accessory grains include monocrystalline detrital micas, unclassified opaque minerals, and zircons.

Linear, point and concavo-convex contacts are recognised among clasts. The intraclasts porosity is occupied by either equant or microcrystalline calcite and ematite cements. The estimated porosity value is qualitatively lower than 5% of the total thin section surface and it is mainly intragranular.

1.12. Sample X89

This sample was taken in the middle part of the Castagnola Fm. (coord. 32T 491,284.8451E 4,945,527.238N) from a normally graded coarse- to very fine-grained sandstone bed.

In the thin section, the rock has a clast-supported, well sorted, texture made of clasts ranging from coarse/medium- to fine-grained sandstone. The clastic fraction is composed of angular to sub-rounded (low-sphericity) feldspar clasts, sub-angular to rounded (high-sphericity) quartz clasts, and angular to sub-rounded (low-sphericity) lithic fragments. Quartz clasts are chiefly monocrystalline, even though polycrystalline clasts subordinately occur. Polycrystalline metamorphic clasts (rich in quartz, feldspars, and micas), fine-grained volcanics, serpentineschists, and serpentinites are recognised as lithic fragments. Accessory grains include monocrystalline detrital micas, well rounded glauconite clasts, chlorite clasts, unclassified opaque minerals, and bioclasts.

Linear, point and concavo-convex contacts are recognised among clasts. The intraclasts porosity is occupied by either equant or microcrystalline calcite and ematite cements. The estimated porosity value is qualitatively between 20 and 30% of the total thin section surface and it is mainly intragranular.

1.13. Sample X90

This sample was taken close to the top of the Castagnola Fm. (coord. 32T 491,269.8129E 4,945,560.056N) from a ca. 1.5 m-thick, normally graded coarse- to very fine-grained, strongly cemented, sandstone bed (i.e., k-bed #2).

In the thin section, the rock has a clast-supported, well sorted, texture made of clasts ranging from fine- to medium-grained sandstone. The clastic fraction is composed of sub-angular to rounded (high-sphericity) quartz clasts, angular to sub-rounded (low-sphericity) feldspar clasts, and sub-angular to sub-rounded (low-sphericity) lithic fragments. Quartz clasts are chiefly monocrystalline, even though polycrystalline clasts subordinately occur. Polycrystalline metamorphic clasts (rich in quartz, feldspars, and micas), fine-grained volcanics, serpentineschists, and serpentinites are recognised as lithic fragments. Accessory grains include monocrystalline detrital micas, well rounded glauconite clasts, chlorite clasts, glaucophane, epidote, unclassified opaque minerals, and bioclasts.

Linear, concavo-convex and point contacts are recognised among clasts. The intraclasts porosity is occupied by calcite and ematite cement and, by fine-grained carbonate matrix. The estimated porosity value is qualitatively lower than 5% of the total thin section surface and it is mainly intragranular.

1.14. Sample X25

This sample was taken close to the base of the “Membro di Rocca Crovaglia” of the Costa Montada Fm. (coord. 32T 486,625.1742E 4,945,613.689N) into a medium- to coarse-grained sandstone bed.

In the thin section, the rock has clast-supported, moderately sorted, texture made of clasts ranging from fine/medium- to coarse-grained sandstone. The clastic fraction is composed of sub-angular to angular (high-sphericity) quartz clasts, angular to sub-angular (low-sphericity) lithic fragments, and sub-angular (low-sphericity) feldspar clasts.

Accessory grains include well rounded (high-sphericity) glauconite, epidote and glaucophane clasts and bioclasts (replaced by equant calcite cement).

Linear, concavo-convex, sutured and point contacts are recognised among clasts. The intra-clasts porosity is occupied by equant calcite cement and, subordinately, by microcrystalline calcite cement. The estimated porosity value is qualitatively lower than 5% of the total thin section surface and it is mainly intragranular.

1.15. Sample X34a

This sample was taken close to the base of the “Membro di Rocca Crovaglia” of the Costa Montada Fm. (coord. 32T 491,507.8657E 4,946,386.938N) from a medium-grained sandstone bed.

In the thin section, the rock has clast-supported, well sorted, texture made of medium-grained sandstone clasts. The clastic fraction is composed of rounded- to well rounded (high-sphericity) quartz clasts, sub-angular to angular (low-sphericity) feldspar clasts, and angular to sub-rounded lithic fragments. Quartz clasts are either embayed (i.e., volcanic) or polycrystalline. Serpentinites, serpentineschists and polycrystalline metamorphic clasts are recognised as lithic fragments.

Accessory grains include well rounded (high-sphericity) glauconite, unclassified opaque minerals and bioclasts (porous or replaced by equant calcite cement).

Mainly linear and point contacts are recognised among clasts, even though rare concavo-convex and sutured clast contacts can occur. The intraclasts porosity is occupied by equant calcite cement and, subordinately, by microcrystalline calcite cement. The estimated porosity value is qualitatively lower than 5% of the total thin section surface.

1.16. Sample X34b

This sample was taken close to the base of the “Membro di Rocca Crovaglia” of the Costa Montada Fm. (coord. 32T 491,507.8657E 4,946,386.938N) from a normally graded coarse- to fine-grained sandstone bed.

In the thin section, the rock has clast-supported, moderately sorted, texture made of clasts ranging from fine- to coarse-grained sandstone. The clastic fraction is composed of sub-rounded to rounded (high-sphericity) quartz clasts, angular to sub-rounded (low-sphericity) feldspar clasts, and angular to sub-angular (low-sphericity) lithic fragments. Quartz clasts are either embayed (i.e., volcanic) or polycrystalline. Serpentinites, serpentineschists and polycrystalline metamorphic clasts are recognised as lithic fragments.

Accessory grains include well rounded (high-sphericity) glauconite, chlorite (as replacement of feldspars), glaucophane, unclassified opaque minerals and bioclasts (porous or replaced by equant calcite cement).

Mainly linear and point contacts are recognised among clasts, even though rare concavo-convex and sutured clast contacts can occur. The intraclasts porosity is occupied by equant calcite cement and, subordinately, by microcrystalline calcite cement. The estimated porosity value is qualitatively lower than 5% of the total thin section surface.

1.17. Sample X37

This sample was taken close to the top of the “Membro di Rocca Crovaglia” of the Costa Montada Fm. (coord. 32T 489,808.7508E 4,945,263.902N) from a normally graded coarse- to fine-grained sandstone bed.

In the thin section, the rock has clast-supported, moderately sorted, texture made of clasts ranging from fine- to coarse-grained sandstone. The clastic fraction is composed of well rounded (high-sphericity) quartz clasts, sub-angular to angular (low-sphericity) feldspar clasts, and angular to sub-angular (low-sphericity) lithic fragments. Quartz clasts are either embayed (i.e., volcanic) or polycrystalline. Serpentinites, serpentineschists and polycrystalline metamorphic clasts are recognised as lithic fragments.

Accessory grains include well rounded (high-sphericity) glauconite, monocrystalline detrital micas, chlorite (as replacement of feldspars), glaucophane, unclassified opaque minerals and bioclasts (porous or replaced by equant calcite cement).

Mainly linear and point contacts are recognised among clasts, even though rare concavo-convex and sutured clast contacts can occur. The intraclasts porosity is occupied by equant calcite cement and, subordinately, by microcrystalline calcite cement. The estimated porosity value is qualitatively lower than 5% of the total thin section surface. Serpentinite and serpentinoschist fragments are partially replace by fine-grained undifferentiated mineral phases giving them a brownish color in parallel nichols view.

1.18. Sample X36

This sample was taken close to the base of the “Membro di Ronchi” of the Costa Montada Fm. (coord. 32T 491,143.0349E 4,946,048.55N) from a normally graded coarse- to fine-grained sandstone bed.

In the thin section, the rock has clast-supported, moderately to well sorted, texture made of clasts ranging from fine- to medium-grained sandstone. The clastic fraction is composed of well rounded (high-sphericity) quartz clasts, angular to sub-angular (low-sphericity) feldspar clasts, and angular to rounded (low-sphericity) lithic fragments. Quartz clasts are either embayed (i.e., volcanic) or polycrystalline. Serpentinites, serpentineschists and polycrystalline metamorphic clasts (rich in quartz and white-micas) are recognised as lithic fragments.

Accessory grains include well rounded (high-sphericity) glauconite, monocrystalline detrital micas, chlorite (either as replacement of feldspars or as pseudomatrix), glaucophane, unclassified opaque minerals and bioclasts (porous, replaced by equant calcite or polycrystalline quartz cement).

Mainly point and linear contacts are recognised among clasts, even though subordinate concavo-convex and sutured clast contacts can occur. The intraclasts porosity is occupied by microcrystalline calcite cement. The estimated porosity value is qualitatively lower than 5% of the total thin section surface. Serpentinite and serpentinoschist fragments are partially replace by microcrystalline unclassified mineral phases giving them a brownish color in parallel nichols view.

1.19. Sample X39

This sample was taken close to the base of the “Membro di Ronchi” of the Costa Montada Fm. (coord. 32T 488,198.0182E 4,945,155.091N) from a medium- to coarse-grained sandstone bed.

In the thin section, the rock has clast-supported, moderately to well sorted, texture made of clasts ranging from medium- to coarse-grained sandstone. The clastic fraction is composed of well rounded (high-sphericity) quartz clasts, angular to sub-angular (low-sphericity) feldspar clasts, and angular to rounded (low-sphericity) lithic fragments. Quartz clasts are either monocrystalline or polycrystalline. Microcline, sanidine and plagioclase can be distinguished among feldspars. Serpentinites, serpentineschists, fine-grained plagioclase-rich volcanics, carbonate mudstones-wackestones and polycrystalline metamorphic clasts (rich in quartz, feldspars, micas and amphiboles) are recognised as lithic fragments.

Accessory grains include well rounded (high-sphericity) glauconite, glaucophane, and bioclasts (replaced by equant calcite).

Point, concavo-convex and linear contacts are recognised among clasts. The intraclasts porosity is occupied by microcrystalline calcite cement. The estimated porosity value is qualitatively lower than 2% of the total thin section surface and it is mainly intergranular (as microporosity). Feldspars are typically replaced by calcite even though they preserve the original germination.

1.20. Sample X101

This sample was taken close to the base of the “Membro di Cascina Garino” of the Costa Montada Fm. (coord. 32T 491,149.9224E 4,946,565.579N) from fine-grained sandstone bed.

In the thin section, the rock has clast-supported, well sorted, texture made of clasts ranging from fine- to very fine-grained sandstone. The clastic fraction is composed of well rounded (high-sphericity) quartz clasts, sub-rounded to angular (low-sphericity) feldspar clasts, and well rounded to angular (low-sphericity) lithic fragments. Quartz clasts are either monocrystalline or polycrystalline. Sanidine, microcline and plagioclase can be distinguished among feldspars, which typically may be fully replaced by calcite cement. Serpentinites, serpentineschists, micas, and polycrystalline metamorphic clasts (rich in quartz, feldspars, and micas) are recognised as lithic fragments.

Accessory grains include well rounded (high-sphericity) glauconite, glaucophane, oriented monocrystalline detrital micas (to form a sub-mm thick lamination), epidote, and unclassified opaque minerals.

Point, linear, and concavo-convex contacts are recognised among clasts. The intraclasts porosity is pervasively occupied by microcrystalline calcite cement, leading to have a porosity nearby 0% of the total thin section surface.

1.21. Sample X102

This sample was taken in the middle part of the “Membro di Cascina Garino” of the Costa Montada Fm. (coord. 32T 488,879.0504E 4,945,447.022N) from a medium- to very fine-grained sandstone bed.

In the thin section, the rock has clast-supported, moderately sorted, texture made of clasts ranging from medium- to fine-grained sandstone. The clastic fraction is composed of well rounded (high-sphericity) quartz clasts, sub-angular to sub-rounded (low-sphericity) feldspar clasts, and well rounded to angular (low-sphericity) lithic fragments. Quartz clasts are either embayed (i.e., volcanic) or polycrystalline. Microcline, sanidine and plagioclase can be distinguished among feldspars, which typically form the fine-grained sandstone fraction. Serpentinites, serpentineschists, micas, and polycrystalline metamorphic clasts (rich in quartz, feldspars, micas, and amphiboles) are recognised as lithic fragments.

Accessory grains include well rounded (high-sphericity) glauconite, glaucophane, and bioclasts (replaced by equant calcite).

Point and concavo-convex, and subordinately linear, contacts are recognised among clasts. The intraclasts porosity is occupied by microcrystalline calcite cement. The estimated porosity value is qualitatively lower than 2% of the total thin section surface and it is mainly intergranular (as microporosity).

1.22. Sample X104

This sample was taken close to the top of the “Membro di Cascina Garino” of the Costa Montada Fm. (coord. 32T 489,034.8312E 4,945,461.387N) from a normally graded medium- to fine-grained sandstone bed.

In the thin section, the rock has clast-supported, moderately to well sorted, texture made of clasts ranging from medium- to fine-grained sandstone. The clastic fraction is composed of well rounded (high-sphericity) quartz clasts, sub-angular to sub-rounded (low-sphericity) feldspar clasts, and well rounded to angular (low-sphericity) lithic fragments. Quartz clasts are either monocrystalline or polycrystalline. Microcline and plagioclase can be distinguished among feldspars. Serpentinites, serpentineschists, micas, and polycrystalline metamorphic clasts (rich in quartz, feldspars, and micas) are recognised as lithic fragments.

Accessory grains include well rounded (high-sphericity) glauconite, monocrystalline detrital micas, epidote, and bioclasts (replaced by equant calcite).

Point, linear, and concavo-convex contacts are recognised among clasts. The intraclasts porosity is occupied by microcrystalline calcite cement. The estimated porosity value is qualitatively lower than 2% of the total thin section surface and it is mainly intergranular (as microporosity).

1.23. Sample X30

This sample was taken close to the base of the Costa Areasa Fm. (coord. 32T 489,497.6497E 4,946,026.43N) from a normally graded medium- to fine-grained sandstone bed.

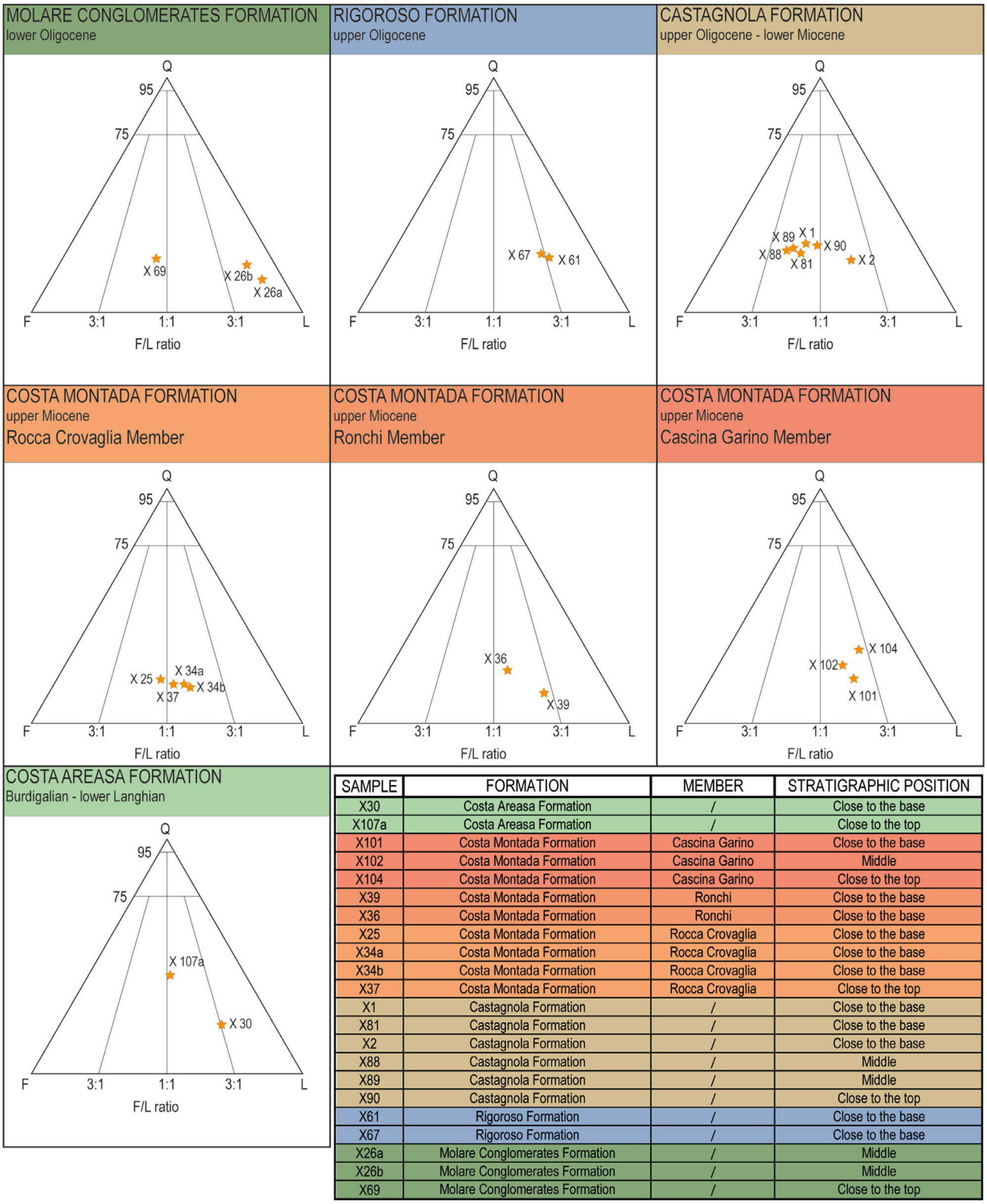
In the thin section, the rock has clast-supported, well sorted, texture made of clasts ranging from fine- to medium-grained sandstones. The clastic fraction is composed of sub-rounded to sub-angular (high-sphericity) quartz clasts, sub-angular to angular (low-sphericity) feldspar clasts and sub-rounded to sub-angular (low-sphericity) lithic fragments. Quartz clasts are either monocrystalline or polycrystalline. Microcline, sanidine and plagioclase can be distinguished among feldspars, with some of them that are sericitized or replaced by calcite cement. Serpentinites, serpentineschists, micas, and polycrystalline metamorphic clasts (rich in quartz, feldspars, and micas) are recognised as lithic fragments. Accessory grains include well rounded (high-sphericity) glauconite and bioclasts (replaced by polycrystalline quartz cement).

Point, concavo-convex and, subordinately, linear contacts are recognised among clasts. The intraclasts porosity is occupied by microcrystalline calcite cement. The estimated porosity value is qualitatively lower than 5% of the total thin section surface and it is intragranular and intergranular (as microporosity).

1.24. Sample X107a

This sample was taken close to the top of the Costa Areasa Fm. (coord. 32T 488,182.8252E 4,947,584.06N) from a fine- to medium-grained sandstone bed.

In the thin section, the rock has clast-supported, well sorted, texture made of clasts ranging from fine- to medium-grained sandstones. The clastic fraction is composed of rounded to sub-angular (high-sphericity) quartz clasts, sub-angular to angular (low-sphericity) feldspar clasts and rounded to angular (low-sphericity) lithic fragments. Quartz clasts are either monocrystalline or polycrystalline. Microcline, sanidine and plagioclase can be distinguished among feldspars, with some of them that are sericitized or replaced by calcite cement. Serpentinites, serpentineschists, micas, and polycrystalline metamorphic clasts (rich in quartz, feldspars,



SAMPLE	FORMATION	MEMBER	STRATIGRAPHIC POSITION
X30	Costa Areasa Formation	/	Close to the base
X107a	Costa Areasa Formation	/	Close to the top
X101	Costa Montada Formation	Cascina Garino	Close to the base
X102	Costa Montada Formation	Cascina Garino	Middle
X104	Costa Montada Formation	Cascina Garino	Close to the top
X39	Costa Montada Formation	Ronchi	Close to the base
X36	Costa Montada Formation	Ronchi	Close to the base
X25	Costa Montada Formation	Rocca Crovaglia	Close to the base
X34a	Costa Montada Formation	Rocca Crovaglia	Close to the base
X34b	Costa Montada Formation	Rocca Crovaglia	Close to the base
X37	Costa Montada Formation	Rocca Crovaglia	Close to the top
X1	Castagnola Formation	/	Close to the base
X81	Castagnola Formation	/	Close to the base
X2	Castagnola Formation	/	Close to the base
X88	Castagnola Formation	/	Middle
X89	Castagnola Formation	/	Middle
X90	Castagnola Formation	/	Close to the top
X61	Rigoroso Formation	/	Close to the base
X67	Rigoroso Formation	/	Close to the base
X26a	Molare Conglomerates Formation	/	Middle
X26b	Molare Conglomerates Formation	/	Middle
X69	Molare Conglomerates Formation	/	Close to the top

Fig. 3. Ternary plots for the studied succession representing the quantitative composition of each analyzed sample.

and micas) are recognised as lithic fragments. Accessory grains include well rounded (high-sphericity) glauconite, monocrystalline detrital micas, chlorite, epidote, and bioclasts.

Point, concavo-convex, sutured, and linear contacts are recognised among clasts. The intra-clasts porosity is occupied by microcrystalline calcite cement. The estimated porosity value is qualitatively lower than 2% of the total thin section surface and it is mainly intergranular (as microporosity).

Geological map

Simplified geological map of the studied area. This figure shows the position of the petrographic samples analyzed.

Qualitative petrographic analysis

This figure shows all the main grain type observed during the analysis. For each grain there is a picture with both parallel and crossed nicols.

Quartz-Feldspar-Lithic ternary plots (QFL)

QFL ternary plots are represented subdivided by formation along with a table that summarize the samples collected. With these diagrams we could observe the change in composition between the base and the top of each formation.

Key analytical stages

Table that summarises the key analytical stage of the microscopic analysis.

Quantitative petrographic tables

2. Experimental Design, Materials and Methods

To collect each sample, we dig into the outcrop surface for 20 cm in order to remove the superficial rock interface typically influenced by strong meteoric weathering. After having removed it, each sample was collected as hard rock by means of geological hammer, packed into the own plastic bag to keep its state uncorrupted, and transferred to the thin section laboratory at University of Milan.

Once thin sections were realized following the worldwide standard procedure, petrographic description of samples was carried out qualitatively and quantitatively through a binocular polarized-light microscope (Leica DMLSP). Microphotographs were taken by means of microscope camera (Zeiss, Axiocam 208 color).

The qualitative description aims to give an overview of the rock texture, grain components, and main diagenetic processes [11–16] and it is based on the simple observation and description by the operator.

On the other hand, the quantitative description aims to give an actual estimation of the rock components (see Fig. 2 for examples) and is based on "Gazzi-Dickinson point-counting" method (see [17] for a detailed analysis of the methodology, Fig. 4).

The "Gazzi-Dickinson point-counting" method [17] is a commonly accepted counting standard method which allows to obtain a modal composition for fine/medium- to medium/coarse-grained sandstones by means of three analytical steps, defined as: (1) Whole composition (i.e., terrigenous, allochemical and orthochemical constituents), (2) Principal composition (i.e., quartzose, feldspathic and lithic grains), (3) Framework-fraction composition (i.e., metamorphic, volcanic and sedimentary fragments of the framework).

Following these analytical steps, data are collected with a progressively higher detail. This method allows to minimize the effect of the grain selection upon the sediment composition.

Two main mineral units can be considered in this method: (1) the fine-textured unit which consists of mineral crystals < 62 µm in size, and (2) coarse-textured unit which consists of mineral crystals > 62 µm. If monomineralic grains are made of crystals > 62 µm, they are included in the coarse-textured unit. Conversely, if monomineralic grains are made of crystals < 62 µm, they are in the fine-textured unit.

Differently, polymineralic grains are considered in a bipartite way according to the average size of their internal constituents (i.e., crystals). If polymineralic grains are formed by internal constituents > 62 µm in size, they are classified as coarse-textured. Conversely, if polymineralic grains are formed by internal constituents < 62 µm in size, they are classified as fine-textured.

In order to reduce the influence of grain size upon the composition (which is typically expressed by the increase of polymineralic grains as the grain size increases, [19]), crystals $>$ 62 µm in size included in grains are considered equivalent to single-crystal grains of similar mineralogical composition. On the other hand, a lithic fragment is counted when the crossline micrometer intercepts a crystal < 62 µm in size [18].

Table 1
Modal whole composition for the lower part of the studied succession.
In this table the counted values for principal composition and accessory grains are reported for samples X26a, X26b, X69, X61, X67, X81, X1, X2, X88, X89, X90.

Geological Unit	Molare Fm.			Rigoroso Marlstones		Castagnola Fm.					
Stratigraphic position	Mid	Mid	Top	Base	Base	Base	Base	Base	Mid	Mid	Top
Sample Name	X26a	X26b	X69	X61	X67	X81	X1	X2	X88	X89	X90
Modal whole composition											
Principal composition grains											
Quartz											
Monocrystalline	1.1	2.0	3.0	5.2	5.9	13.4	15.8	3.8	15.6	12.1	8.8
Polycrystalline coarse-grained	0.7	1.4	1.0	2.7	2.8	2.6	3.2	5.1	2.3	2.3	5.5
Polycrystalline fine-grained	2.9	4.7	4.2	2.5	1.7	1.9	1.3	3.1	0.0	1.6	2.8
Chert	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
In igneous rock fragment	0.9	1.1	0.0	0.5	0.0	1.1	2.1	0.5	1.0	1.0	0.8
In metamorphic rock fragment	2.0	1.6	0.5	0.2	0.2	0.0	0.3	0.5	0.0	0.0	0.0
In volcanic rock fragment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
In clastic rock fragment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Feldspars											
K-feld monocrystalline	3.1	3.8	15.2	6.6	8.1	25.8	24.1	12.2	30.9	25.1	20.4
K-feld in igneous rock fragment	0.0	0.2	0.7	0.0	0.5	1.9	4.0	0.8	1.0	0.8	1.1
K-feld in metamorphic rock fragment	0.0	0.2	0.0	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0
K-feld in volcanic rock fragment	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.2	0.0
K-feld in clastic rock fragment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Plg monocrystalline	0.7	1.1	0.2	1.6	0.5	3.2	3.5	1.3	1.8	1.8	1.7
Plg in igneous rock fragment	0.0	0.0	0.2	0.0	0.0	0.6	0.0	0.8	0.0	0.0	0.0
Plg in metamorphic rock fragment	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Plg in volcanic rock fragment	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0
Plg in clastic rock fragment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Lithics											
Metamorphic	17.9	17.8	6.2	18.6	19.7	11.1	11.5	20.9	10.6	11.7	13.8
Serpentineschist	0.4	0.0	0.0	0.9	0.2	10.0	3.5	0.3	2.5	1.8	0.6
Volcanic	1.8	1.8	5.0	4.5	3.1	0.0	0.0	4.6	0.0	1.2	4.1
Metamorphic	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Serpentinite	17.9	17.8	6.2	18.6	19.7	11.1	11.5	20.9	10.6	11.7	13.8
Clastic	0.4	0.0	0.0	0.9	0.2	10.0	3.5	0.3	2.5	1.8	0.6
Accessory grains											
Monocrystalline mica and chlorite	4.7	2.5	2.7	4.8	4.0	0.0	0.3	1.8	0.3	1.4	2.5
Mica and chlorite in rock fragment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Monocrystalline heavy (opaque) mineral	1.1	2.0	2.7	2.3	2.1	0.0	0.0	0.0	0.5	0.2	0.6
Heavy (opaque) mineral in rock fragment	2.5	2.3	1.7	1.8	2.4	0.9	1.1	0.8	0.5	0.6	0.6
Calcschist	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sparitic carbonate	16.6	14.0	2.7	4.1	1.9	0.4	8.6	3.6	4.0	1.6	3.0
Dolomite	0.4	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Impure carbonate	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Mudstone-wackestone	2.2	0.9	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0
Packstone-grainstone	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Glauconite	0.0	0.2	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0
Pelitic inclusion	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0
Other NCI	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Bioclast	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.3	0.2	0.0
Other CI	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Unclassified carbonate	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Alterite	2.0	2.5	4.7	1.6	3.1	0.0	0.0	3.8	0.8	0.2	1.7
Pseudomatrix	0.0	0.0	0.0	0.2	0.7	0.0	0.0	0.0	0.0	0.0	0.0
Interstitial and authigenic materials											
Porosity in unclassified grain	0.2	0.5	0.0	0.7	0.2	0.2	0.0	0.0	0.0	0.0	0.0
SiO_2 matrix	0.0	0.0	0.0	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0
$CaCO_3$ matrix	0.0	0.0	1.0	0.0	0.0	0.0	0.5	0.3	0.3	0.0	0.3
SiO_2 cement	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

(continued on next page)

Table 1 (*continued*)

Geological Unit	Molare Fm.			Rigoroso Marlstones		Castagnola Fm.					
Stratigraphic position	Mid	Mid	Top	Base	Base	Base	Base	Base	Mid	Mid	Top
Phyllosilicate cement	0.0	0.0	0.5	0.9	3.1	0.2	0.3	0.5	0.5	0.0	1.1
$CaCO_3$ cement	32.4	32.9	22.4	21.1	18.7	2.3	17.1	26.5	25.6	11.5	19.3
Other cements	0.0	0.0	0.5	0.0	0.0	19.6	0.0	0.5	1.0	1.8	2.8
Intragranular porosity	0.4	0.7	0.7	3.2	0.7	2.8	0.8	0.8	0.0	11.3	1.9
Authigenic plague	0.0	0.0	0.5	5.9	2.6	0.0	1.1	0.0	0.0	0.0	0.3
Oversized porosity	0.0	0.0	0.0	0.0	0.0	1.5	0.0	0.0	0.3	8.4	0.0
Total Rock	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Table 2
Modal framework-fraction composition for the lower part of the studied succession.
In this table the counted values for lithics grains are reported for samples X26a, X26b, X69, X61, X67, X81, X1, X2, X88, X89, X90.

Geological Unit	Molare Fm.			Rigoroso Marlstones		Castagnola Fm.					
Stratigraphic position	Mid	Mid	Top	Base	Base	Base	Base	Base	Mid	Mid	Top
Sample Name	X26a	X26b	X69	X61	X67	X81	X1	X2	X88	X89	X90
Modal framework-fraction composition											
Principal composition grains											
Quartz-biotite schists	1.5	0.6	0.0	1.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Quartz-biotite-feldspars schists	4.1	6.9	0.0	1.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Semi-schists	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Argilloschists	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Microcrystalline mica	2.6	4.0	3.3	4.1	3.4	3.0	1.1	2.1	0.0	5.4	2.0
Quartz-muscovites schists	26.2	26.9	11.3	43.2	42.0	25.0	35.2	45.5	20.0	36.6	37.6
Qartz-Plagioclase-Epidote-Anfiboles schists	6.2	5.1	2.0	4.7	1.7	25.0	11.0	9.0	40.0	18.3	9.9
Chlorite-serpentiniteschists	9.7	10.3	62.7	18.2	40.3	0.0	2.2	20.7	2.9	15.1	22.8
Massive serpentinite	4.1	4.6	13.3	11.5	7.4	0.0	0.0	12.4	0.0	6.5	14.9
Glassy volcanic rocks	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Acid volcanic rocks	0.0	0.0	0.0	0.0	0.6	17.0	5.5	0.0	4.3	4.3	2.0
Intermediate-basic volcanic rocks	1.0	0.0	0.0	3.4	0.0	28.0	8.8	0.7	10.0	5.4	0.0
Volcanoclastic rocks	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Claystone	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Siltstone	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Calcilutites	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Mudstone-Wackestone	5.1	2.3	0.0	0.0	0.0	0.0	1.1	0.0	0.0	0.0	0.0
Bioclastic rocks	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Dolostone	1.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sparitic carbonate	38.5	35.4	7.3	12.2	4.5	2.0	35.2	9.7	22.9	8.6	10.9
Packstone-Grainstone	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Monocrystalline calcite crystal	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL LITHICS	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

For each sample, a minimum of 250 principal composition grains and a minimum of 100 grains belonging to the framework-fraction composition fraction are counted. The counted grains are expressed as relative percentages of the different mineralogical-petrographic categories in modal compositions [17].

Finally, each sample is plotted in a Q-F-L+C (Quartz-Feldspar-Lithics+Carbonates, see Fig. 3) ternary plot [11,20].

Table 3
Modal whole composition for the upper part of the studied succession
In this table the counted values for principal composition and accessory grains are reported for samples X25, X34a, X34b, X37, X36, X39, X101, X102, X104, X30, X107a.

Geological Unit	Costa Montada Fm.									Costa Areasa Fm.	
	Rocca Crovaglia Mbr.				Ronchi Mbr.		Garino Mbr.				
Stratigraphic position	Base	Base	Base	Top	Base	Base	Base	Mid	Top	Base	Top
Sample Name	X25	X34a	X34b	X37	X36	X39	X101	X102	X104	X30	X107a
Modal whole composition											
Principal composition grains											
Quartz											
Monocrystalline	6.4	6.8	5.1	9.2	6.9	7.1	11.3	16.9	7.1	19.6	7.0
Polycrystalline coarse-grained	0.6	0.0	0.0	0.0	0.0	0.0	0.3	0.3	0.0	0.3	0.0
Polycrystalline fine-grained	0.6	0.0	0.8	0.0	3.9	0.6	1.0	1.7	0.0	0.5	2.9
Chert	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
In igneous rock fragment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
In metamorphic rock fragment	3.9	2.3	2.8	1.8	1.7	0.6	2.6	1.1	0.6	4.5	0.4
In volcanic rock fragment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
In clastic rock fragment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.0
Feldspars											
K-feld monocrystalline	7.7	6.3	8.4	11.3	6.1	7.1	8.6	7.6	6.9	7.6	3.5
K-feld in igneous rock fragment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
K-feld in metamorphic rock fragment	6.4	3.3	2.3	2.1	2.7	0.8	1.0	0.8	0.2	1.8	1.6
K-feld in volcanic rock fragment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
K-feld in clastic rock fragment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Plg monocrystalline	8.3	9.0	7.2	12.2	7.9	7.4	6.8	3.7	4.8	6.5	3.3
Plg in igneous rock fragment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Plg in metamorphic rock fragment	4.7	2.3	2.6	2.1	2.2	2.0	2.4	1.1	0.0	1.5	1.2
Plg in volcanic rock fragment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Plg in clastic rock fragment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Lithics											
Metamorphic	6.9	8.0	10.7	12.5	4.9	13.6	13.9	11.6	12.3	8.3	7.2
Serpentineschist	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Volcanic	7.5	7.8	4.1	10.4	3.7	5.7	2.4	7.1	2.7	5.3	2.7
Metamorphic	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Serpentinite	6.9	8.0	10.7	12.5	4.9	13.6	13.9	11.6	12.3	8.3	7.2
Clastic	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Accessory grains											
Monocrystalline mica and chlorite	1.7	0.8	1.3	2.7	1.2	1.4	2.9	1.4	3.4	1.5	0.4
Mica and chlorite in rock fragment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0
Monocrystalline heavy (opaque) mineral	0.0	0.0	0.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Heavy (opaque) mineral in rock fragment	1.7	0.8	2.3	0.0	0.0	1.4	1.3	1.1	2.3	1.5	0.8
Calcschist	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sparitic carbonate	9.9	12.3	14.8	8.0	16.0	21.5	11.8	12.4	7.1	4.5	19.0
Dolomite	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Impure carbonate	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Mudstone-wackestone	0.0	0.0	1.0	0.0	0.0	0.8	0.3	0.0	0.0	0.0	0.0
Packstone-grainstone	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Glauconite	0.0	1.3	1.5	0.6	1.5	0.8	0.0	1.1	2.1	0.5	1.6
Pelitic inclusion	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Other NCI	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Bioclast	3.0	4.8	5.6	0.0	6.6	3.4	0.3	0.3	0.0	0.5	13.3
Other CI	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Unclassified carbonate	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0
Alterite	0.6	0.5	0.5	0.0	0.5	2.0	1.8	0.8	2.3	0.3	0.0
Pseudomatrix	0.3	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Interstitial and authigenic materials											

(*continued on next page*)

Table 3 (*continued*)

Geological Unit	Costa Montada Fm.									Costa Areasa Fm.	
	Rocca Crovaglia Mbr.				Ronchi Mbr.	Garino Mbr.					
Stratigraphic position	Base	Base	Base	Top	Base	Base	Base	Mid	Top	Base	Top
Porosity in unclassified grain	0.0	0.0	0.0	0.0	0.7	0.0	0.0	0.0	0.0	0.0	0.0
SiO_2 matrix	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
$CaCO_3$ matrix	3.9	7.3	3.8	1.8	1.2	2.0	2.9	0.0	0.0	0.0	3.7
SiO_2 cement	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Phyllosilicate cement	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
$CaCO_3$ cement	17.7	21.6	18.9	16.7	23.3	17.0	24.3	24.0	43.5	30.5	28.6
Other cements	0.3	0.0	0.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Intragranular porosity	0.6	0.0	0.5	0.6	2.0	1.1	0.0	0.0	0.0	0.5	0.4
Authigenic plague	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.6	1.0	0.0	0.0
Oversized porosity	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Rock	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Table 4
Modal framework-fraction composition for the upper part of the studied succession
In this table the counted values for lithics grains are reported for samples X25, X34a, X34b, X37, X36, X39, X101, X102, X104, X30, X107a.

Geological Unit	Costa Montada Fm.									Costa Areasa Fm.	
	Rocca Crovaglia Mbr.				Ronchi Mbr.	Garino Mbr.					
Stratigraphic position	Base	Base	Base	Top	Base	Base	Base	Mid	Top	Base	Top
Sample Name	X25	X34a	X34b	X37	X36	X39	X101	X102	X104	X30	X107a
Modal framework-fraction composition											
Principal composition grains											
Quartz-biotite schists	0.0	0.0	0.0	0.0	0.0	0.9	0.0	0.0	2.0	0.0	0.0
Quartz-biotite-feldspars schists	11.0	7.0	9.0	8.0	1.0	5.3	12.7	0.0	3.9	5.8	0.0
Semi-schists	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Argilloschists	0.0	0.0	0.0	0.0	0.0	0.0	2.9	0.0	0.0	1.0	0.0
Microcrystalline mica	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Quartz-muscovites schists	11.0	11.0	9.0	26.0	14.3	14.2	27.5	32.0	41.2	29.1	23.0
Qartz-Plagioclase-Epidote-Anfiboles schists	0.0	10.0	22.0	7.0	3.8	0.0	0.0	0.0	2.9	3.9	0.0
Chlorite-serpentiniteschists	20.0	11.0	12.0	15.0	19.0	17.7	10.8	16.0	14.7	17.5	7.0
Massive serpentinite	26.0	20.0	10.0	24.0	9.5	14.2	8.8	19.0	9.8	23.3	8.0
Glassy volcanic rocks	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Acid volcanic rocks	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Intermediate-basic volcanic rocks	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Volcanoclastic rocks	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Claystone	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Siltstone	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Calcilutites	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Mudstone-Wackestone	0.0	0.0	1.0	0.0	3.8	3.5	1.0	0.0	0.0	0.0	0.0
Bioclastic rocks	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Dolostone	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sparitic carbonate	7.0	6.0	5.0	0.0	5.7	13.3	1.0	3.0	4.9	1.9	12.0
Packstone-Grainstone	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Monocrystalline calcite crystal	25.0	35.0	32.0	20.0	42.9	31.0	35.3	30.0	20.6	17.5	50.0
TOTAL LITHICS	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

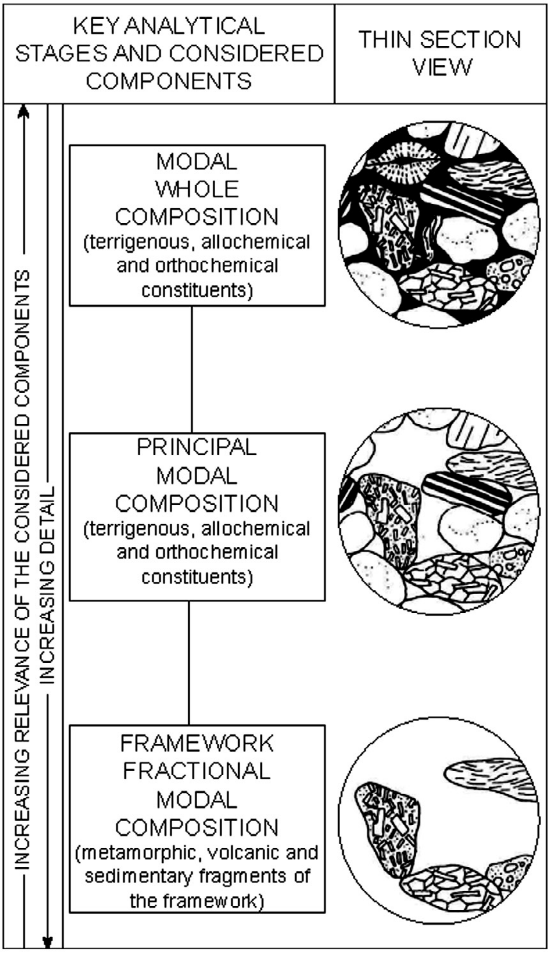


Fig. 4. Key analytical stages for sandstones microscopic analysis. For each one the formal denomination and visualization of the constituents is given. Modified after Di Giulio and Valloni [17].

Ethics Statement

- This material is the authors' original work, which has not been previously published elsewhere.
- The authors did not submit this paper for other publication elsewhere.
- The paper reflects the authors' research and analysis wholly and truthfully.
- The paper properly credits the meaningful contributions of co-authors and co-researchers.
- The results are appropriately placed in the context of prior and existing research.
- All sources used are correctly disclosed (correct citation).
- All authors have been personally and actively involved in substantial work leading to the paper and will take public responsibility for its content.
- No information obtained for experimentation with human subjects was used.
- No information obtained for experimentation with animals was used.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships which have or could be perceived to have influenced the work reported in this article.

Data Availability

Petrography data from the Oligocene-lower Langhian succession of the Arquata Scrivia area in the Tertiary Piedmont Basin (NW Italy) (Original data) (Zenodo)

CRediT Author Statement

D. Invernizzi: Formal analysis, Writing – original draft, Data curation, Investigation; **S. Reguzzi:** Formal analysis, Conceptualization, Methodology, Data curation, Writing – original draft, Investigation, Visualization, Validation; **F. Felletti:** Conceptualization, Writing – original draft, Visualization, Validation.

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