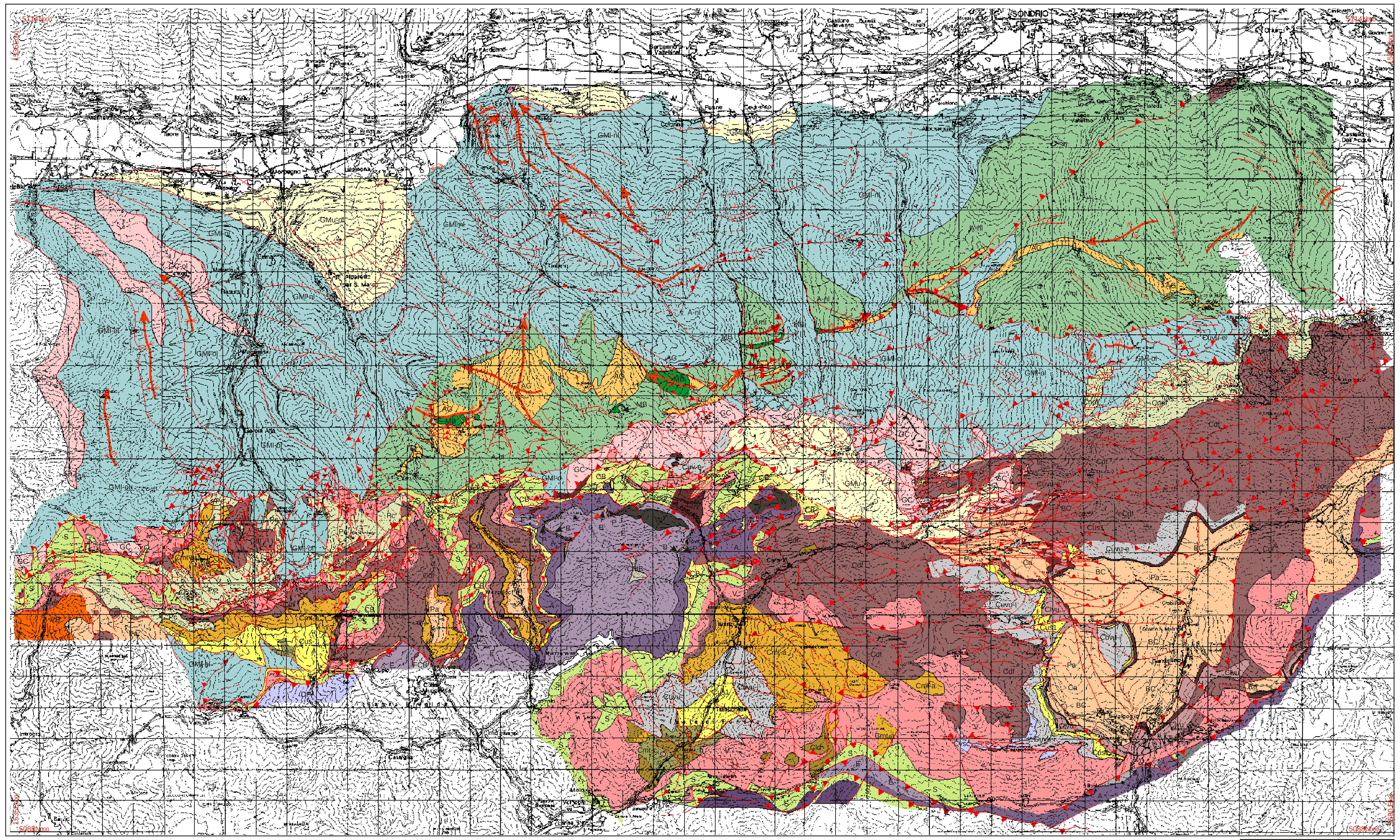
STRUCTURAL GEOLOGICAL MAP OF THE CENTRAL OROBIC ALPS

CARTA GEOLOGICO-STRUTTURALE DELLE ALPI OROBICHE CENTRALI

Mapped and compiled by/Rilevato e compilato di: J. Feijth

Scale/Scala: 1:100.000



Topography from: Carta Tematica Regionale Regione Lombardia 1:50.000; Foglio B3 -Alto Lario- ,Foglio B4 -Como-Lecco- , Foglio C3 -Sondrio- , Foglio C4 -Clusone- .

Legend:

Sediments:

Triassic

Norian

- **DP** – **Dolomia Pricipale/Hauptdolomit (DP)** Light and dark grey dolomites, unbedded to well bedded, according to subtidal, intratidal or supratidal sedimentation conditions. Occasionally bituminous layers occur.

Carnian

- **SGB** – **Formazione di San Giovanni Bianco (SGB)** Redish and greenish or yellow fine sandstones, siltstones and shales, alternating with grey to yellow marly dolomites. Gypsum lenses, cellular dolomites and brecciated limestones are common.
- **G** – **Formazione di Gorno (G)** Well-bedded black limestones alternating with dark marls and shales or sandstones.
- **CMB** – **Calcare Metallifero Bergamasco (CMB)** Micritic limestones and dolomite. Well bedded and with thin tuffaceous intercallations and chert. Ore bearing.

Ladinian

- **E** – **Formazione di Esino (E)** Thick bedded or unbedded limestonesor dolomites in platform facies (forereef, reef and backreef), built up mainly by algae.
- **W** – **Formazione di Wengen (W)** Tuffaceous marls, greenish or grey volcanic or terrigeneous sandstones and siltstones, black marly limestones and shales. Reefal detritus near the platform margins.

Anisian

- **B** – **Formazione di Buchenstein (B)** Light or dark limestones and dolomites, often nodular and with intercallations of marls and grey or green volcanoclastics. The nodules and lenses of black chert are characteristic.
- **P** – **Formazione di Prezzo (P)** Well bedded, rhythmic alternating black micritic limestones or marls and black, carbon-rich shales and siltites. The limestones are partly nodular.
- **CA** – **Calcare di Angelo (CA)** Medium- to well-bedded, partly nodular limestones or occasionally dolomites, light to dark grey, with intercallated fine sanstones and siltstones. The lower part is thick bedded and less nodular than the upper part, which has shaly intercalations.
- **CB** – **Carniola di Bovegno (CB)** Yellow and grey dolomites, often breccated or in form of cellular dolomites, with intercallated thin layers of yellow, green and redsiltstones and shales. The intercalated anhydrites are related to dedolimitisation.

Scythian

- **S** – **Servino (S)** Quartz-arenites and siltstones with some marls grading upward into wackestones with dolomitic cement, then into sandy dolomites and finally into yellow and grey dolomites with thin red and yellow intercallations of siltstones and shales. A general subdivision into an lower terrigeneous and an upper carbonate-richer part is possible.

Permian

Kazanian + Tatarian

- **V** – **Verrucano Lombardo (V)** Pinkish to redish conglomerates with volcanic components and quartz-clasts in alternation with redish and pinkish arenites. Locally greyish green colours, related to reduction. Braided channel and alluvial plain deposits, shallow transitional and coastal deposits towards the east, particularly at the top.

?

Formazione di Collio/Ponteranica:

Ufimian — Upper sedimentary member

- **Cnpf/Pc** – **Northern proximal facies (Cnpf)/Ponteranica conglomerates (Pc)** Dark grey poorly sorted matix-rich or matrix-supported conglomerate with very angular to angular clasts. Occasionally finer sediments, down to siltstone. Clasts derived from low-grade metasediments, Gneiss Chiari and Permian volcanics. Debris flow dominated alluvial fan and scree deposits from inner to outer alluvial fan.
- **Cvsc** – **Val Sanguigno conglomerates (Cvsc)** Grey to green, occasionally very coarse conglomerates and sandstones. Clasts mainly derived from underlying, often andesitic volcanics. Proximal and mid alluvial fan deposits.
- **Cdf** – **Distal facies (Cdf)** Grey coarse to medium sandstone with clay-chips, thick crudely bedded, interbedded with thin discontinuous siltstone distally grading into grey to black medium to fine neatly bedded sandstone and siltstone alternating with thin-bedded or finely laminated shales Latter rarely contain carbonate yellowish dolomite crusts and carbonate mounds pseudomorph after gypsum Braided fluviatile deposits grading into perennial lake sediments and evaporites.

?

Kungurian — Lower volcanoclastic member

- **Cuv-i/Cuv-e** – **Upper volcano-sedimentary unit, Intracalderic (Cuv-i)/Extracalderic (Cuv-e)** Light grey to green porphyritic, often perlitic welded rhyolitic tuffs interbedded with related minor unwelded tuffs, sandstones and shales. Very thick composite cooling units, often underlain by surge deposits and separated by thinner lacustrine deposits, airfall tufs and minor fluviatile sediments.
- **Cld** – **Lavadomes (Cld)** Massive greyish, greenish and occasionally redish rhyolites breaching the overlying and older sequence of basement, basal conglomerate lower volcano-sedimentary unit and upper sedimentary unit 1. The top of these domes is frequently of erosive nature and covered by Verrucano Lombardo. These rhyolites have microcrystalline porphyric and vitrophyric textures, occasionally with spherulites, and often a well-developed alpine foliation.
- **Cmtc** – **Lavadome-related massflows and turbidites, conglomeratic facies (Cmtc)** Conglomerates and breccias, with a matrix of ash, containing greenish and violet porphyritic pumices/clasts, most probably derived from the lower volcanoclastic unit, on top and along the flanks of the lavadomes. These massflow units grade distally into turbidites, which grainsize changes rapidly away from the domes.
- **Cmta** – **Lavadome-related massflows and turbidites, arenitic facies (Cmta)** The distal equivalent of Cmtc, with predominantly arenites deposited as turbidite. The fine layers consist of fine siltsstones and shales.

?

Artinskian

- **Cus1** – **Upper sedimentary unit 1 (Cus1)** Well bedded andesitic sandstone, minor siltstone and towards the top fine unwelded tuffs. Intracalderic braided stream deposits and lacustrine sediments. Thickness distribution and progressive unconformity around a zone of condensed deposition point to an unstable floor rising during deposition at Costa d'Agnone/Monte della Croce, possibly in relation to the development of a cryptodome.

?

Sakmarian

- **Ca** – **Andesites (Ca)** Andesitic, dark grey to green lavas, porphyry and breccia deposited as flows and subvolcanic bodies.

?

Asselian

- **CLVu** – **Lower volcanosedimentary unit (Clvu)** Welded acid tuffs of red to purple colours. From bottom to top vitric to porphyritic. Those are interbedded with red volcanogenic conglomerate and sandstone and multi-coloured siltstone, sandstone, and towards the top more fine unwelded tuffs. Lower intracalderic coarse braided river and lacustrine deposits containing one or very few ash-flows.

?

C

- **BC** – **Basal Conglomrates (BC)** Red, and greyisch quartz- and basement-clast rich conglomerate and sandstone interbedded with red-purplish burrowed siltstone. There are some thin and very discontinuous lenses of andesitic sandstone at the basement-contact (at Laghi Curiosi). Braided river deposits interbedded with lacustrine and distal alluvial plain sediments.

Basement:

Meta- sedimentary and Volcanic units

Post-Sardic sequence of the 'Orobic fold nappe'

- **Gmu ol/nl** – **Upper Gneiss di Morbegno (Gmu)** Lithotype (b) is abundant: Biotite and albite-rich paragneisses with abundant typical albite-porphyroblasts with fine garnet-, biotite-, quartz- and occasional muscovite inclusions. Shows locally a metadioritic character and grades into rocks with almost isotropic texture, without foliation or bedding. Metamorphic fabric related to dehydration melting reaction of biotite. Other lithologies include less distinctive usually garnet-bearing psammo-pelitic rocks, phyllites and schists with garnet and occasionally albite-porphyroblasts and amphibole.
- **GCol/nl** – **Gneiss Chiari del Corno Stella (GC)** Massive foliated homogeneous leucocratic coarse-grained metarhyolites (calcalkaline) with a granoblastic and rarely flaser texture with typical large K-Feldspar porphyroblasts, quartz, muscovite and minor albite. Thin muscovite layers, with or without chlorite, that curve around layers and lenses of quartz and granoblastic feldspars, form the main foliation Sheets parallel to layering of the Gneiss di Morbegno. With a well-developed foliation that is continuous with the main foliation of the Gneiss di Morbegno. This lithology locally has a mylonitic character.
- **Gml ol/nl** – **Lower Gneiss di Morbegno (Gml)** Occurs as lithotype (a) near the contacts of the Gneiss Chiari: Garnet-staurolite-white mica schist containing occasionally some kyanite and tourmaline. Albite and to a lesser extent K-feldspar usually present, but biotite often absent. Other lithologies: Less distinctive usually garnet-bearing, psammo-pelitic rocks, phyllites and schists with garnet and occasionally albite-porphyroblasts and amphibole.

Pre-Sardic sequence of the 'Orobic fold nappe'

- **A ol/nl** – **Filladi di Ambria (A)** Schists, quartzitic-schists and chlorite-schists with subordinate thinner meta-greywackes and quartzites with locally a well-developed centimetre- to decimetre-scale layering, particularly where quartzitic layers are abundant. Locally garnet and amphibole are common. Where the protolith has the appropriate chemical composition, which is particularly the case nearby the 'GOOV' garnet is abundant. This unit contains D_2-refolded D_1-folds.
- **MB** – **Metabasites (MB)** (1) 100m to km-scale lenses and layers of amphibolite-schists and epidote-amphibolite-schists with moderately defined occasionally chaotic layering and locally some garnet. Cross bedding and laminations have been observed, pointing to a sedimentary or a volcano-sedimentary origin. (2) Complexes of fine-grained amphibolite sills of up to 3m thickness consisting of fine-grained euhedral magmatic amphibole in a matrix of symplectitic plagioclase and epidote. Locally, at the base of the sills, there are up to dm-size with xenoliths of meta-gabbro, meta-amphibolite and ultramafic rock.

L. Cambrian-E. Tremadocian

- **Pa** – **Parautochton (Pa)** Quartz-mica schists, phyllites and meta-conglomerates with some garnet, often chlorite-rich. These rocks have a strong tectonic overprint. Variscan layering-parallel shearing, whereby low-angle extensional shear-bands developed, gave these rocks a strong curviplanar character. Rootless folds have been developed in quartzite-layers and the meta-conglomerates contain strongly flattened and sheared clasts. Alpine overprint is mainly cataclastic. Amphibolitic dykes occur near Mezzoldo.

The extensions ol and nl respectively indicate structural positions in the overturned limb and normal limb of the Orobic fold nappe.

Igneous units

Late-Variscan

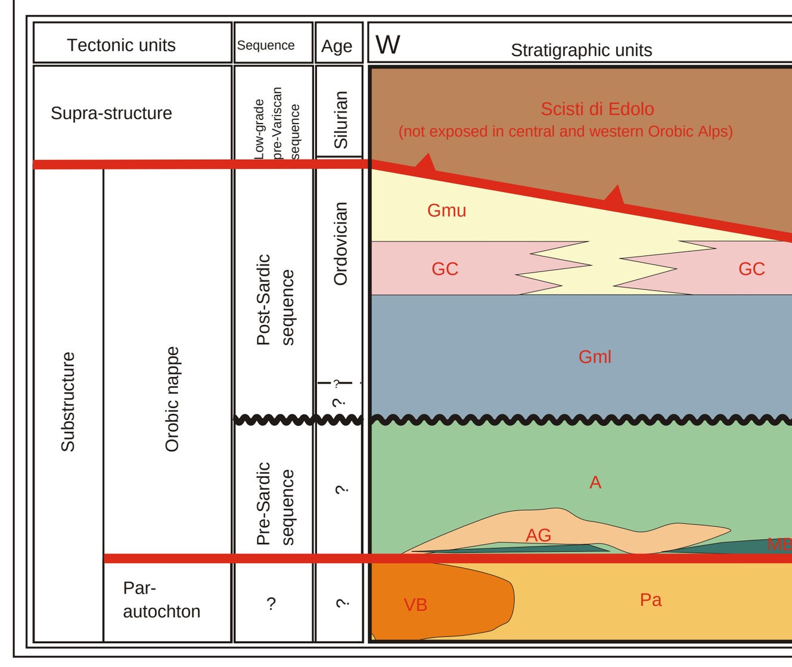
- **VB** – **Val Biandino plutonic complex (VB)** Syn late-tectonic tonalites, granites, quartz-diorites and gabbro-diorites. The contactmetamorphic aureole contains hornfels with sillimanite and cordierite. These intrusions are generally conformable to folded bedding, but at places discordant, especially at the apophyses.

Late-Sardic

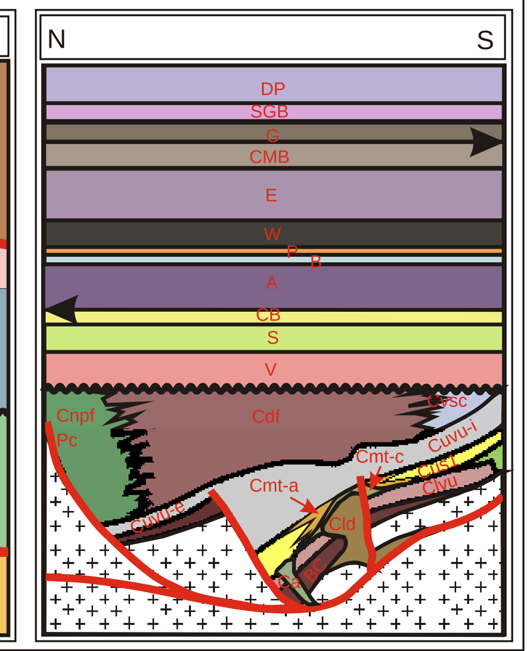
- **AG** – **'Gneiss Occhiadini Orobico-Valtellinese' ('GOOV')** Dark granodioritic augengneisses or metagranitoids, locally mylonitic, with centimetric K-feldspar in a matrix of quartz, muscovite, albite, biotite, chlorite and along the contacts often garnet. These rocks occur predominantly along.the stratigraphic level of the metabasites as sills and stocks. Post-collisional type granite (peraluminous and subalkaline) with unconformable relationships with folded layering of the host-rock, that is also present as xenoliths. The main foliation with crenulated compositional layering corresponds to the main foliation in the upper sequence of the 'Orobic fold-nappe'.

Stratigraphic relationships:

Orobic basement:



Cover:



Tectonic symbols:

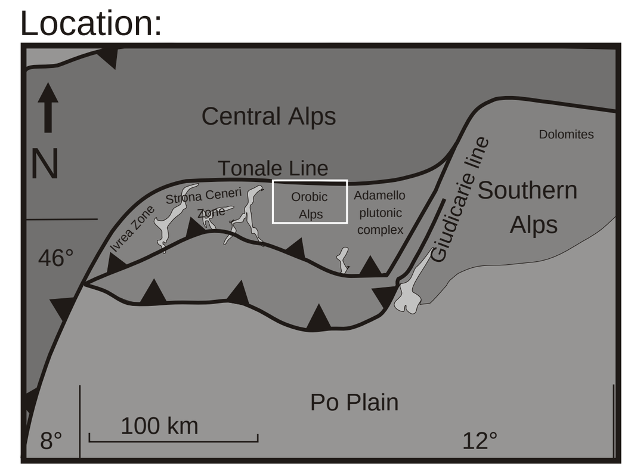
- Normal fault
- Thrust
- Fault with dominant strike-slip component and detachment at inliers of basement in Collio basin
- Anticline
- Syncline

Important note on the fault-symbols: Faults and shearzones developed and were reactivated during the Ordovician, Variscan, Permian and Alpine phases. Variscan kinematics caused development of thrusts, transtensional detachments, extensional- and strike-slip shearzones. During the Permian only normal and strike-slip faults developed, existing faults reactivated as such and Variscan transtensional detachments were also reactivated.

Those Palaeozoic tectonic grains reactivated during the Alpine phases. All thrusts indicated on this map are of Alpine age, mostly reactivated Palaeozoic structures. Alpine normal faults occur at the southern margin of the basin, as adjustments to vertical reverse movements at inverted Permian normal faults.

Dashed faults (– – – – – –) are inferred.

Location:



Based on field-mapping by the author and maps published by: de Sitter & de Sitter-Koomans (1949), Cassati & Gnaccolini (1967), Cadel et al. (1996) and Montrasio (1990).