The African Mattherhorn : yes or no? : A structural, geodynamical and paleogeographical overview

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The African Matterhorn: yes or no? – a structural, geodynamical and paleogeographical overview

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Summary of a presentation given at the VSP/ASP annual convention, Sion, Switzerland, June 2008.

The geological landscape in the Zermatt Region shows that the pyramid of the Matterhorn appears as a small continental raft run aground on strata of marine sediments, witness of a long vanished ocean (Fig. 1).
On the block diagram (Fig. 2), a schematic three-dimensional view of the Alpine structure, the high Alps of Valais are now no more than a klippe (the Dent Blanche nappe), a small remnant of the Lower Austro-Alpine unit, from Apulian (or Adiatic) origin. These Klippen are underlain (dark grey) by the Tsaté and Zermatt Nappes (Upper Penninic), both from oceanic origin (Piemont Ocean). Below (in light grey), refolded with Tsaté, the Middle Penninic nappes of Briançonnais

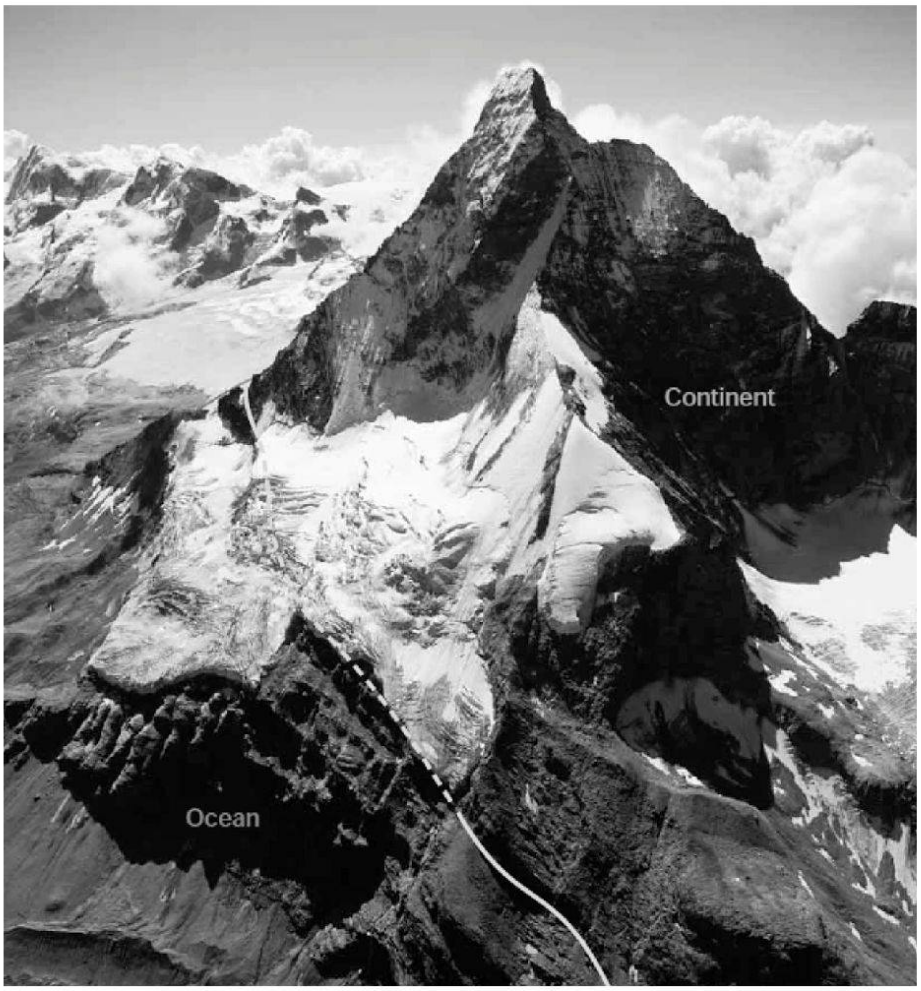

Fig. 1:
Aerial view of the Matterhorn from north (source: Marthaler 2005).

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origin, representing a mostly shallower marine environment underlain by continental crust.

This superposition is beautifully visible from the Gornergrat (Fig. 3, 4). Stucturally from base to the top: The basement rocks of Briançonnais origin (continental lower plate, here the Monte Rosa and Lyskamm) are dipping west under a sequence of serpentinite and ophiolite, representing the oceanic crust (here Breithorn and Little Matterhorn). More in the western direction, the Dent Blanche nappe (klippe of continental upper plate) forms the high peaks of the Valaisan Alps, from the Matterhorn to the Weisshorn.

The cross-section from SE to NW (Escher et al. 1997) in Fig. 5 shows the three main units in greater details.

The history of the alpine orogenic cycle is related to the evolution of the Tethys and its later deformation by the closing-in of Africa against Europe. The Tethys oceanisation started at early Jurassic times (Fig. 6A). Between Europe and Northern Africa (Apu-

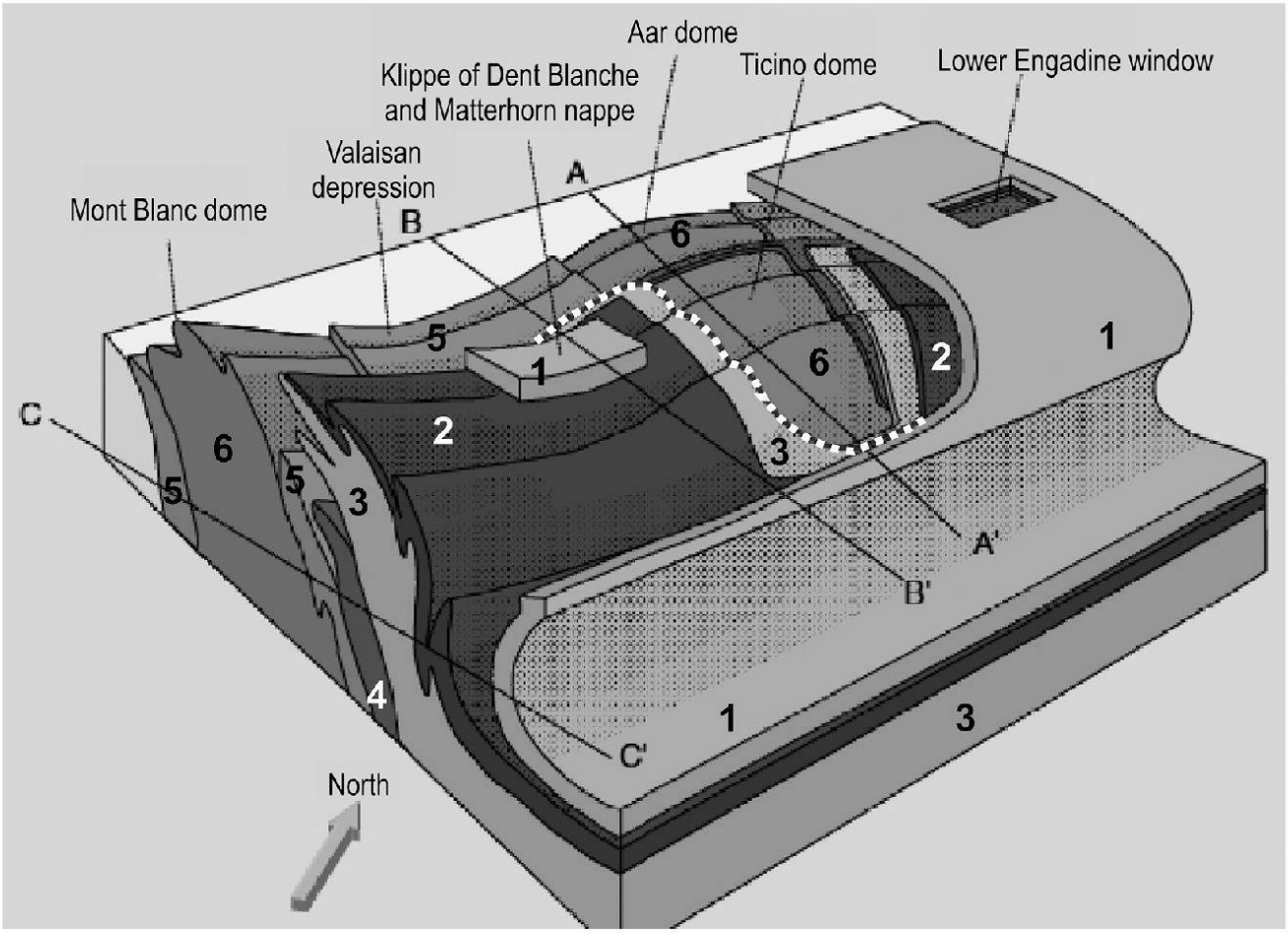

Fig. 2: In this simplified block diagram, adapted from Burri (1992), back folds have not been drawn. Note the longitudinal curvature of the forward folds, giving rise to the preservation of sediments of the Helvetic nappes in the Valaisan depression, whereas in the massifs of Mont Blanc and Aar updoming continental crust is exposed at surface. The strongly uplifted Ticino dome has laid bare the European bedrock. The overlying pile of Penninic and Austro-alpine nappes have been entirely eroded away. These nappes are still conserved in the Eastern Alps (Austria and the Engadine Valley) and in central parts of the Valais. The high Alps of the Canton Valais are representing a Klippe (known as the Dent Blanche nappe, out of which the Matterhorn itself is carved), a small remnant of an Austro-alpine unit from the northern edge of the Apulian plate, that was once much larger than it is at present. [1] Austro-alpine nappes, [2] upper Penninic nappes, [3] middle Penninic nappes, [4] metasedimentary, lower Penninic nappes, [5] Helvetic nappes, [6] external crystalline massif and lower Penninic nappes; Simplon fault (dotted line).

lia), the Piemont Ocean is opening thanks to the spreading of a very active mid-oceanic ridge. In Zermatt we can observe pillow lava, nicely demonstrating the oceanic nature of this crust.The Jurassic pillow shape is well preserved in spite of an overprint by an early Tertiary metamorphism.

During Cretaceous times, the tectonic regime changed from the opening of the Tethys to a progressive closing, initiating the Alpine orogenic event (Fig. 6B). The southern margin is becoming active, with oceanic subduction under Apulia. An accretionary prism is building, witness of the vanished ocean (today the Tsaté and Zermatt nappes). The separation of the Briançonnais from the European continent lasted until early Tertiary when, with the continuous shortening of the northern Valaisan Trough, the subduction became continental, as testified by the high pressure metamorphism of part of the Briançonnais (the Monte Rosa in particular). The landscape of the Moiry region (Fig. 7) illustrates this development in a masterly way.

The emplacement of the Matterhorn Klippe, representing Apulian/African continental crust, on the underlying oceanic crust of the Piemont Trough, occurred during late Oligocene.

The African Matterhorn: yes or no? – The answer is double: Yes for the rocks, no for the shape. The cause of this change is the plate tectonic history of the Alps.

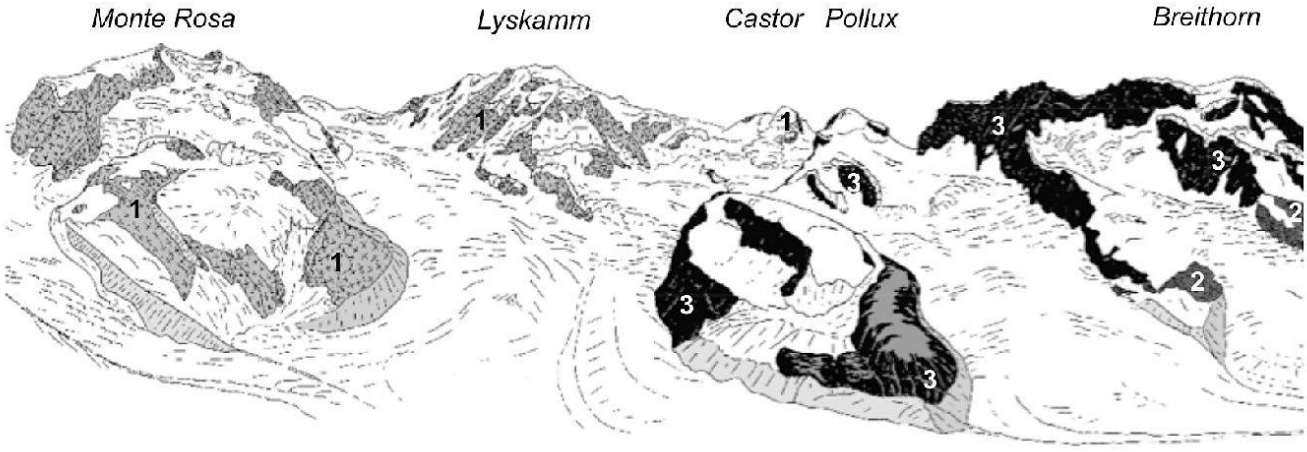

Fig. 3: Panorama from the Gornergrat, drawn by M. Sartori, Departement of Geology and Paleontology, University of Geneva. A view on two continents and the remains of a vanished ocean. [1] Briançonnais basement: granites, gneisses (Protero-Paleozoic); [2] Oceanic metasediments: mainly calcareous schists (Jurassic-Cretaceous); [3] Oceanic crust (ophiolite): metabasalts, metagabbros, serpentinites (Jurassic). Tectonic setting: [1] Monte Rosa nappe, [2/3] Zermatt - Saas Fee Zone.

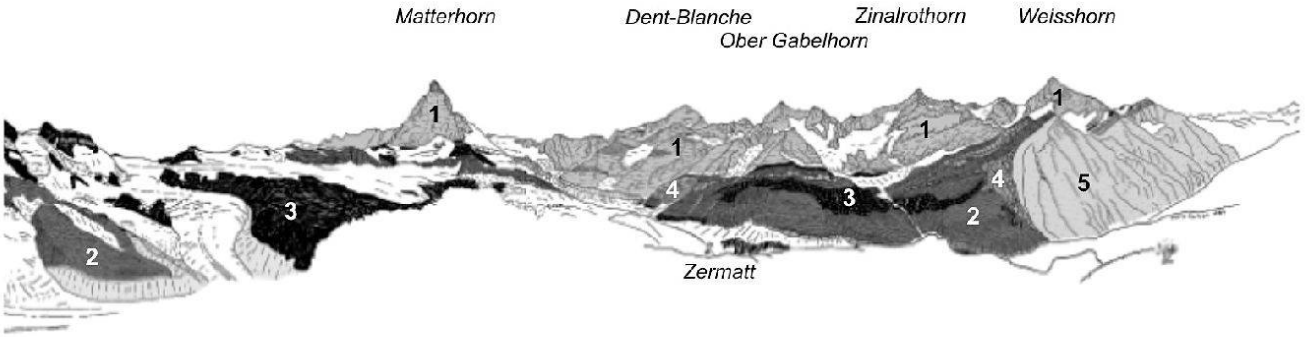

Fig. 4: Panorama from the Gornergrat, continued from Fig. 3. [1] Austro-alpine basement: granitic gneisses, gneisses and metagabbros (Paleozoic); [2] Oceanic metasediments: mainly calcareous schists («Schistes lustrés») (Jurassic-Cretaceous); [3] Scraps of oceanic crust: metabasalts, metagabbros (Jurassic); [4] Sediments from the Briançonnais platform: quartzites, dolomites, marbles (Permian to Tertiary); [5] Briançonnais basement: granites, gneisses (Protero-Paleozoic). Tectonic setting: [1] Dent-Blanche nappe, [2/3] Tsaté nappe or Combin Zone, [4/5] Siviez-Mischabel nappe.

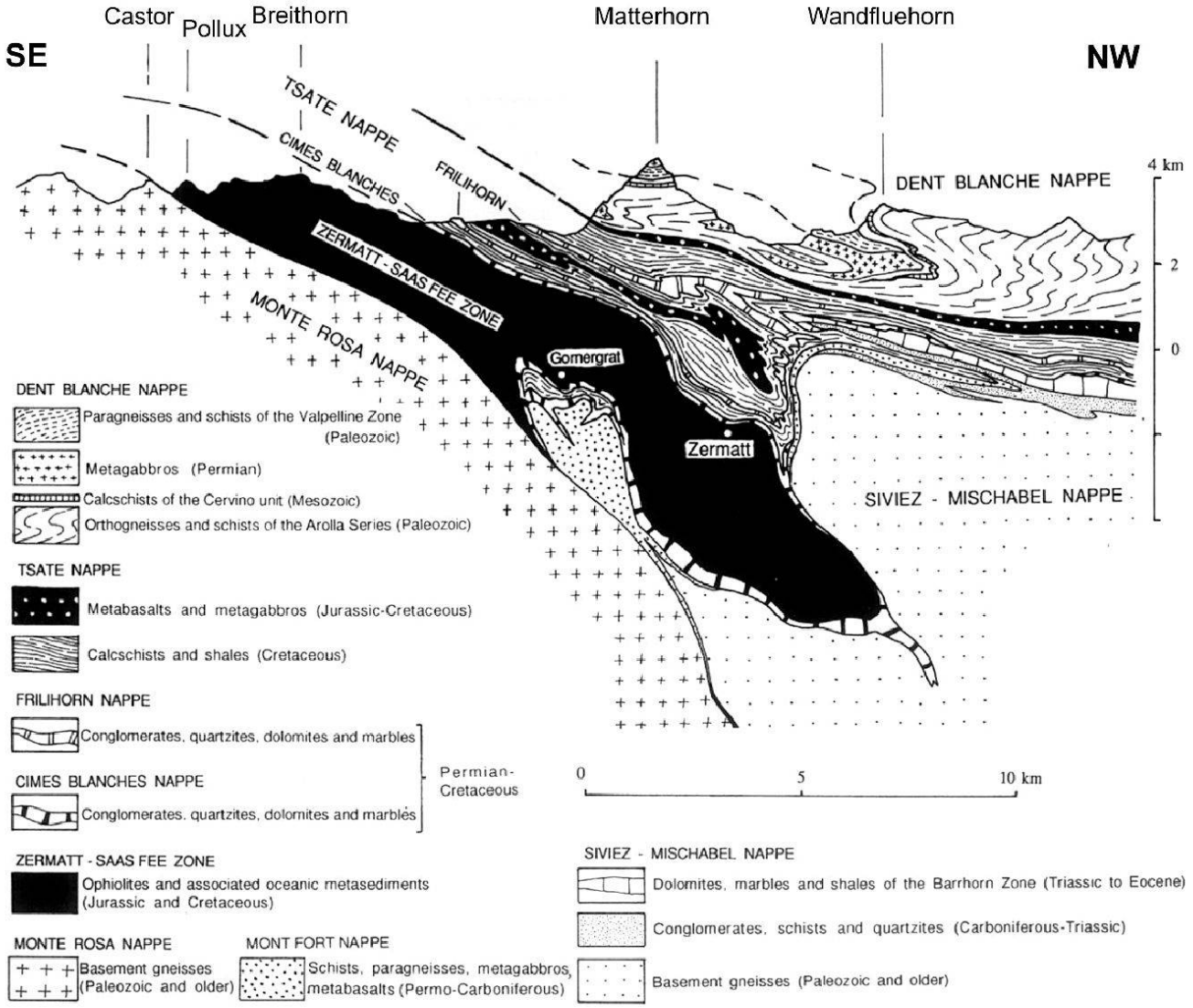

Fig. 5: Simplified geological cross-section showing the relation between the Monte-Rosa, Siviez-Mischabel, Zermatt-Saas Fee, Tsaté and Dent Blanche nappes in the Zermatt region (Escher et al. 1997).

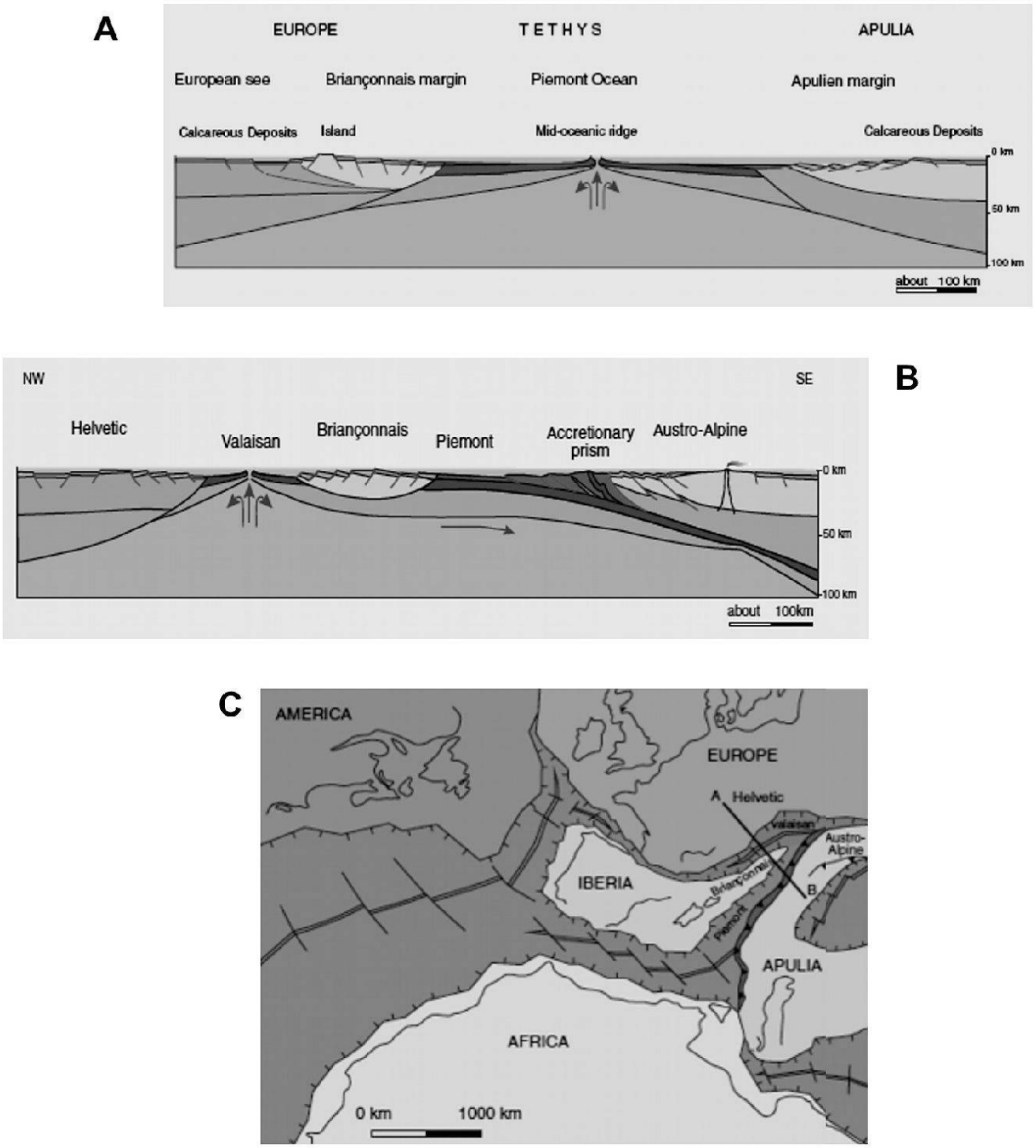

Fig. 6: (A) Cross-section through the Piemont Ocean at mid Jurassic: Tethys oceanisation started at early Jurassic times. Between Europe and Northern Africa (Apulia), the Piemont Ocean is opening due to spreading along its mid-oceanic ridge. (B) Cross-section at mid Cretaceous: Opening of the Valaisan Ocean and subduction of the Piemont oceanic crust underneath the apulian plate. While subduction continues, oceanic crust is planed off, giving rise to the formation of the accretionary prism. (C) Mid-cretaceous paleogeography showing the position of sections A and B. Figure adapted from Stampfli 1993, 1998.

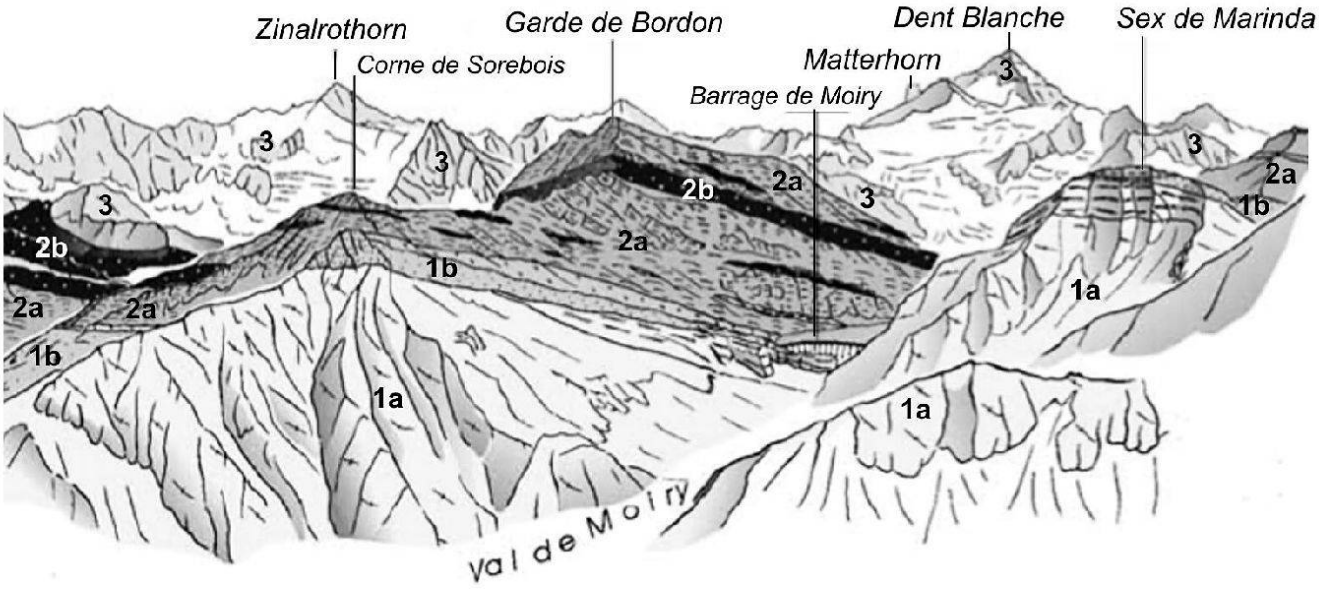

Fig. 7: The continent-ocean-continent superposition: a fundamental feature of high-Alpine landscapes in Canton Valais. Same superposition as shown in Fig. 4, but from NW. [1] Paleozoic gneisses of the Apulian continental crust (Dent Blanche nappe); [2a] Cretaceous schists: Piemont oceanic metasediments (Tsaté nappe); [2b] Jurassic ophiolites, scrapped oceanic crust (Tsaté nappe); [3a] Paleozoic gneisses, micaschists and amphibolites of the Briançonnais continental margin (Siviez-Mischabel nappe); [3b] Permo-triassic quartzites: continental sediments of the Briançonnais margin. Tectonic setting: [1] Apulia, old african continent, [2] remnants of a vanished ocean, accretionary prism, [3] Iberia, European continent. Panorama drawn by M. Sartori, Departement of Geology and Paleontology, University of Geneva.

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