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Polyphase deformation in the Col Bechei area (Dolomites – Northern Italy)

By Carlo Doglioni[1]) and Chiara Siorpaes[2])

ABSTRACT

The Col Bechei area is located in the eastern Southern Alps where the Dinaric Paleogene thrust belt is overprinted by the Neogene Southalpine thrust belt. The orientations of the two thrust belts are almost perpendicular and their overlap has produced an interference pattern within the brittle regime in the central-eastern Dolomites. The main structural evolution that can be detected in this area is the following: A) Tensional Mesozoic tectonics, indicated by N-S trending normal growth faults which determine sedimentary thickness variations. B) WSW-vergent folds and thrusts ("Dinaric" trend) of Paleogene age. C) SSE-vergent thrusts and folds ("Southalpine" trend) of Neogene age. The geometry of each phase has been inherited by the later tectonics. The tectonic evolution is recorded in spectacular outcrops of the Col Bechei-Monte Parei area. The Dinaric deformation generated a WSW-vergent tight recumbent fold in the hangingwall of a low angle thrust plane. The structure was later deformed by two S-vergent thrust planes perpendicular to the earlier structure with frontal and oblique ramps with inclinations ranging between 25° and 60°. The geometry of structures outcropping in the Col Bechei area represents an example of tectonic interference pattern between two oblique thrusts belts.

RIASSUNTO

L'area del Col Bechei è posta nelle Alpi Meridionali orientali dove è presente la sovrapposizione della catena di sovrascorrimenti Dinarica e della catena di sovrascorrimenti Sudalpina. Le due catene sono quasi perpendicolari e la loro sovrapposizione ha prodotto delle figure d'interferenza in regime fragile nelle Dolomiti centro-orientali. L'evoluzione strutturale che può essere ricostruita in quest'area è la seguente: A) Tettonica distensiva Mesozoica, testimoniata da faglie normali di direzione media N-S, le quali hanno determinato variazioni di spessore delle coeve sequenze deposizionali. B) Pieghe e sovrascorrimenti a vergenza OSO di direzione tipicamente Dinarica e di età Paleogenica. C) Sovrascorrimenti e pieghe a vergenza SSE di direzione Sudalpina e di età Neogenica. Ogni fase ha agito come geometria ereditata per la fase seguente. La suddetta evoluzione tettonica è osservabile negli affioramenti spettacolari dell'area del Col Bechei e Monte Parei. La deformazione Dinarica ha prodotto una piega stretta-isoclinale rovesciata, a vergenza OSO, a tetto di un sovrascorrimento a basso angolo. La struttura è stata successivamente deformata da due sovrascorrimenti S-vergenti taglianti perpendicolarmente la struttura precedente in rampe frontali e oblique con inclinazioni variabili tra 25° e 60°. L'attuale geometria affiorante nell'area del Col Bechei rappresenta un esempio di struttura d'interferenza tra due catene di sovrascorrimenti tra loro normali.

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Introduction

One still undervaluated aspect of thrust tectonics, particularly in foreland imbrication zones, is the structural analysis of areas where different tectonic phases of oblique orientation are superimposed. These structures can only be resolved in three dimensions and volume balancing has to be taken into account (i.e. LAUBSCHER 1988). This paper illustrates an example of perpendicular superposition of two thrust belts from the Dolomites (Southern Alps – Northern Italy). The geometry and the kinematic evolution of the Col Bechei area are presented as a case of structural interference by such oblique overprint (Fig. 1).

Geological setting

The Col Bechei-Monte Parei mountains are located in the central-eastern Dolomites (Fig. 2), whose structure is mainly a large pop-up-related syncline of Neogene age. Previous structural studies have been published by KOBER (1908), SCHWINNER (1915), MERLA (1931), OGILVIE-GORDON (1929, 1934), ACCORDI (1955) and LEONARDI (1955, 1967). This area represents a key location in the tectonic reconstruction of the Dolomites, because of the occurrence of a Late Oligocene-Early Miocene conglomerate (the Monte Parei Conglomerate, CITA & ROSSI 1959, CROS 1966, 1978, BOSELLINI pers. comm.) which post-dates a compressive tectonic phase with a W-vergent "Dinaric" trend deforming Mesozoic rocks (COUSIN 1981, DOGLIONI 1985, 1987, 1990, DOGLIONI & BOSELLINI 1987). The same conglomerate is subse-

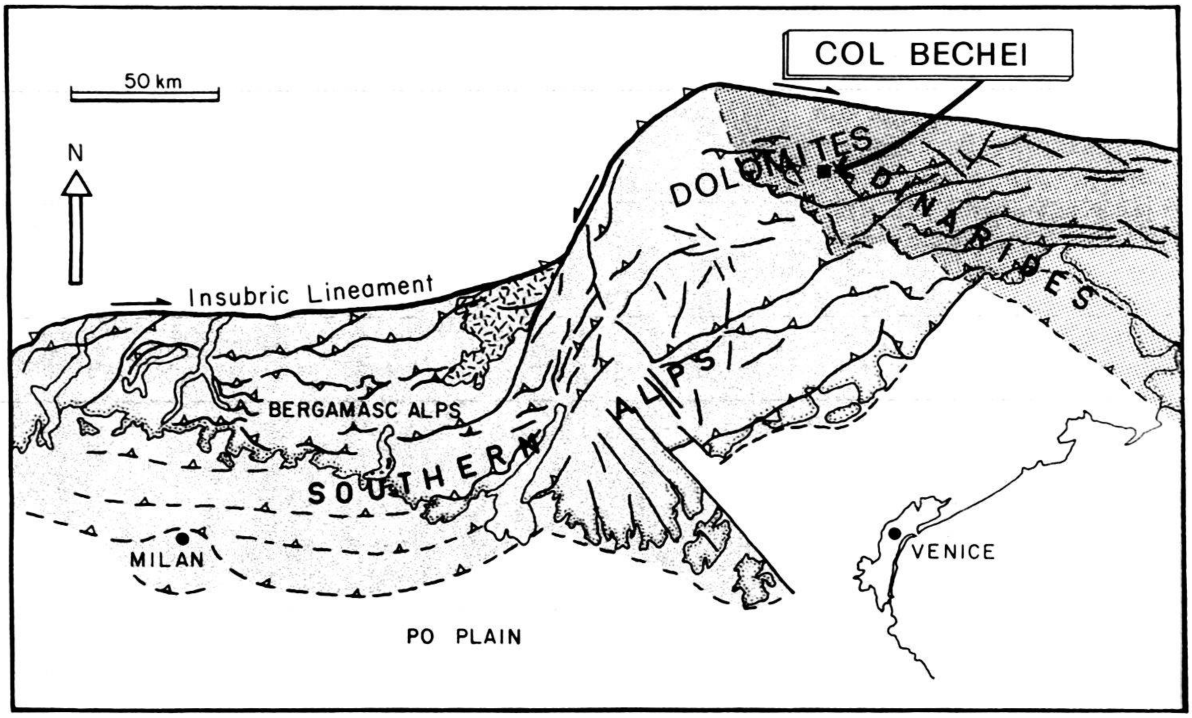


Fig. 1. The Col Bechei is located within the region of heavy stipple, indicating interference between the WSW-vergent Dinaric thrust belt and the SSE-vergent Southalpine thrust belt.

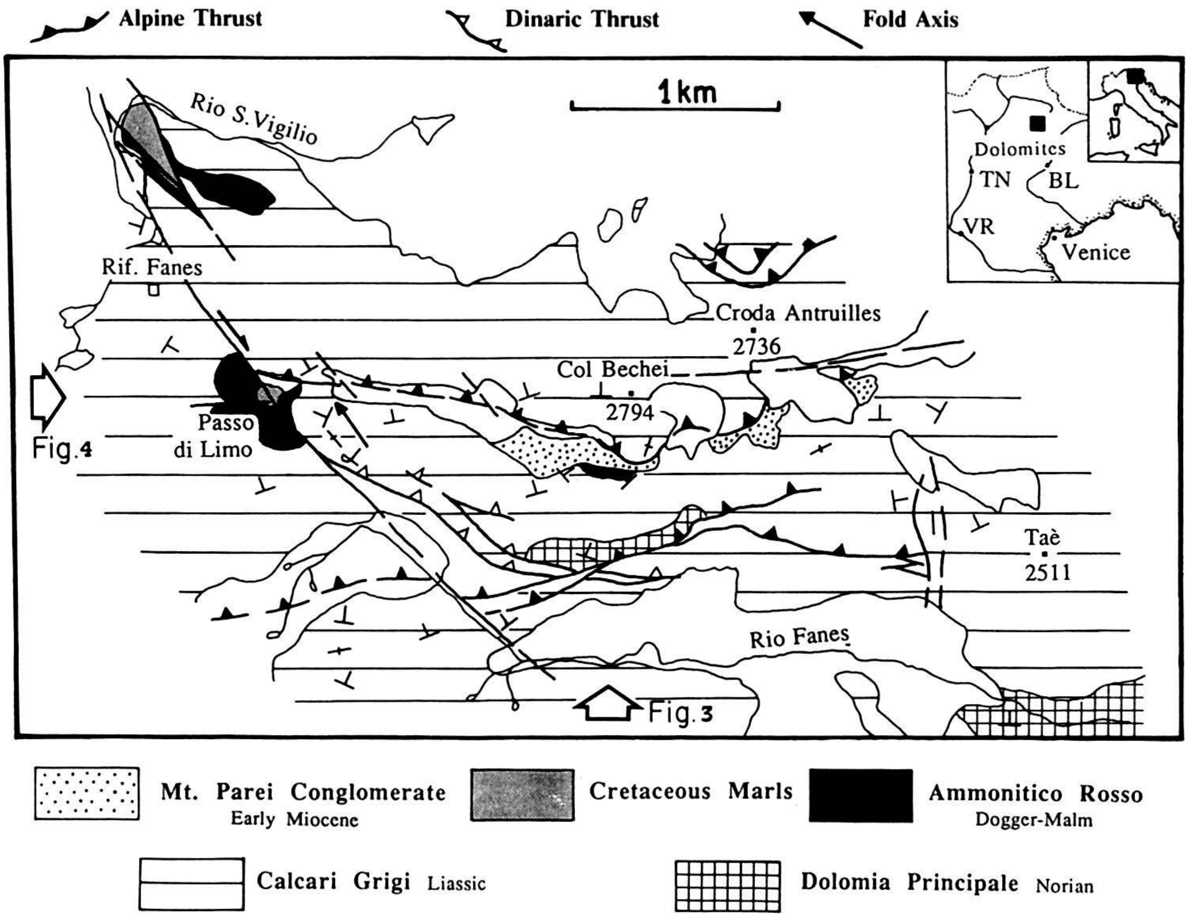
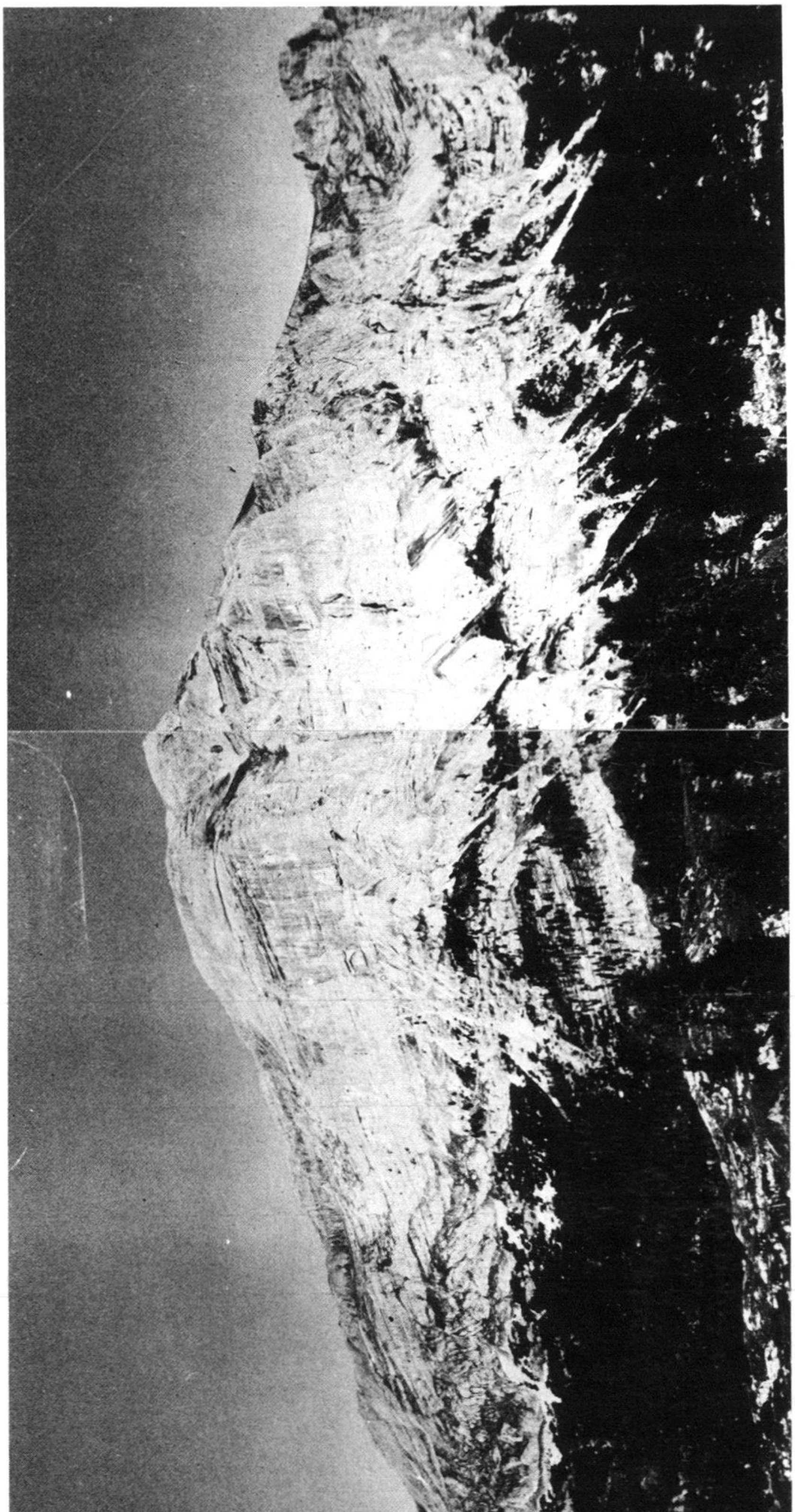


Fig. 2. Geologic map of the Col Bechei area. Large arrows indicate the viewpoint for related figures. The Dachstein Limestone (Rhaetian) is not differentiated and is considered at the base of the Calcari Grigi.

quently cut by S-vergent "Southalpine" thrusts. The Col Bechei-Monte Parei area is, therefore, very important for the following reasons: (1) It is the only location to allow dating of the tectonic phases in the Dolomites, and (2) the excellent exposures allow a 3D analysis of the two perpendicular compressive tectonic phases. The presence of S-vergent thrust tectonics of Cretaceous age (Eoalpine phase) is suggested to occur mainly northward of the examined region and the area was probably located at that time along the foredeep of this orogeny.

Structural analysis

The southern cliff of the Col Bechei allows a series of structural observations (Fig. 3). A wide tight fold, within Late Triassic rocks (Dolomia Principale) in the core, is located in the hangingwall of a 5°–30° eastward-dipping thrust plane. The fold axis trends N40°–20°W and undulates, changing orientation southwards (N20°–0°W) in the nearby Vallon Bianco area (not contained in Fig. 2). Minor parasitic folds have the same trend. The overthrust forms ramps (~30°) in the Calcari Grigi (Liassic), Dachstein Limestone (Rhaetian) and Dolomia Principale (Norian), with a hinterland dipping duplex (Boyer & Elliott 1982, Mitra 1986). At the top of the Calcari Grigi



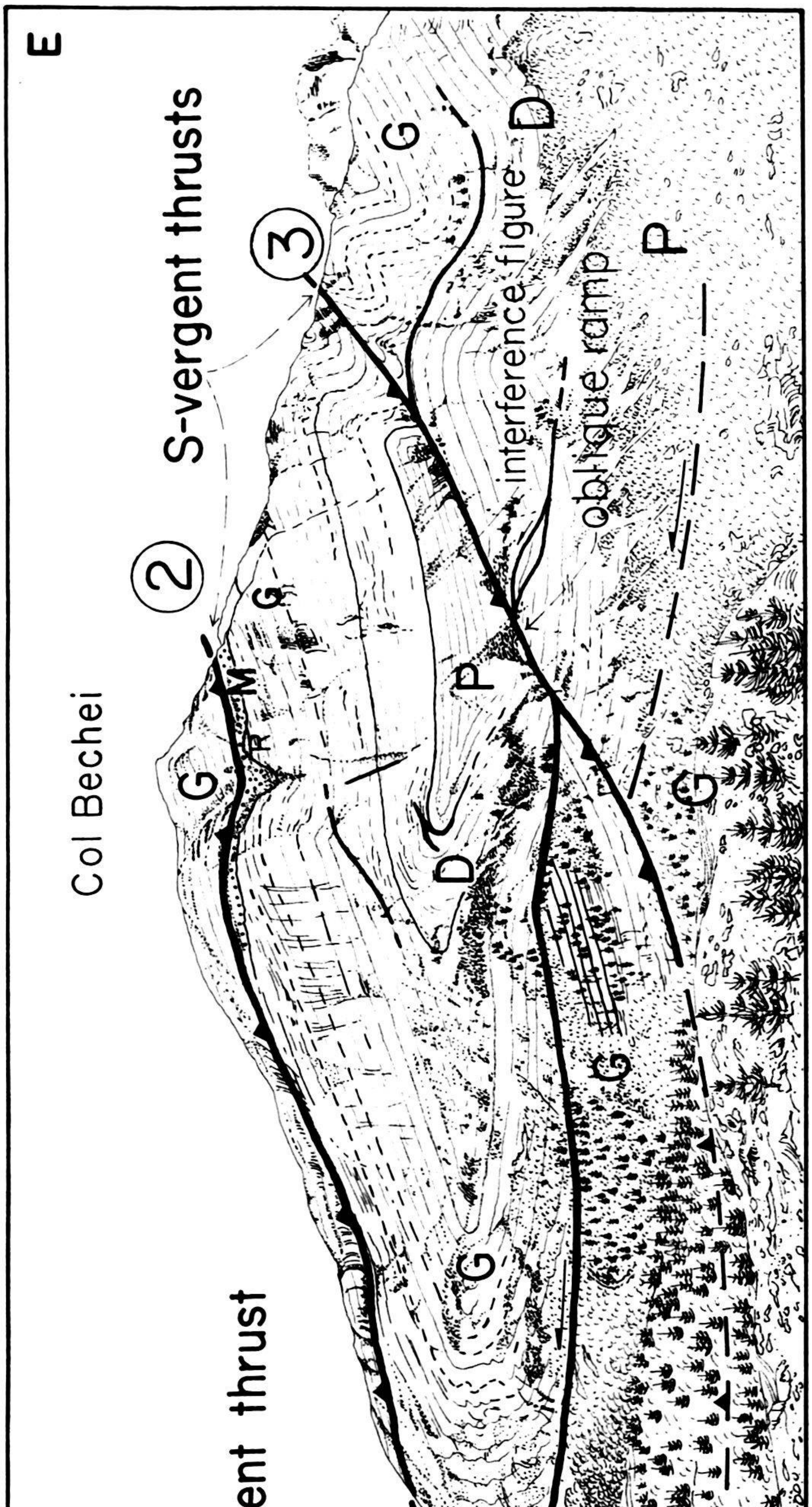


Fig. 3. The Col Bechei structure as viewed from the south: the W-vergent thrust sheet (1) is cut by the S-vergent overthrusts (2 and 3). Numbers, in addition, indicate the kinematic progression. Legend: P, Dolomia Principale (Norian); D, Dachstein Limestone (Rhaetian); G, Calcari Grigi (Liassic); R, Rosso Ammonitico (Dogger-Malm); M, Monte Parei Conglomerate (Oligocene–Early Miocene). Thrust number 1 is due to the Dinaric pre-Monte Parei Conglomerate compression. Thrusts numbers 2 and 3 are linked to the Southalpine post-Monte Parei Conglomerate (Neogene) compression. Note the interference figure generated by the overprint of the two perpendicular tectonic phases.

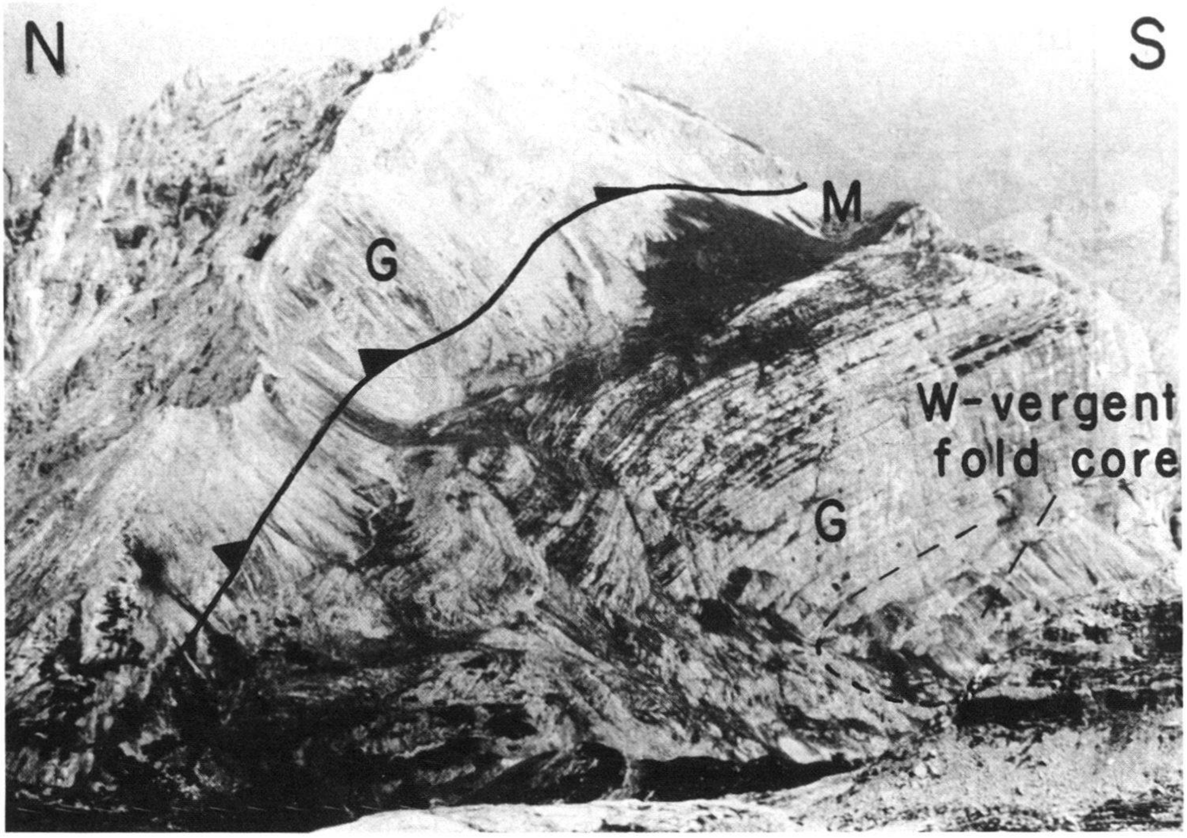


Fig. 4. View from the west of the Col Bechei structure. Note the oblique view of the W-vergent fold (Dinaric) which is cut by the S-vergent overthrust (Alpine), number 2 of Fig. 3. Legend: G, Calcari Grigi (Liassic); M, Monte Parei Conglomerate (Early Miocene).

and Rosso Ammonitico the overthrust forms a flat, with dips of 5°–10°. The recumbent geometry of the hangingwall fold (Figs. 3 and 4) suggests a fault-propagation folding origin (Suppe 1983, 1985) for this feature, close to its tip line.

In the footwall of the Col Bechei overthrust, there occur N-S striking normal faults (Fig. 5) which often exhibit a syn-Calcari Grigi (Liassic) age, as demonstrated by common syn-sedimentary thickening of the hangingwall beds. A clear example is observed in the footwall of the overthrust within the northern cliff of the Vallon Bianco, just to the south of the Col Bechei (Fig. 5). Small scale normal faults outcrop in the Calcari Grigi of the Passo di Limo, rising toward the Col Bechei. The best example of a normal faulting occurs a few kilometers to the west, southwest of the Forcella Lavarella (at the contact between the Carnian Cassian Dolomite in the footwall and the Norian Dolomia Principale in the hangingwall), where the fault shows extensional striations and the hangingwall is characterized by a rollover anticline. The Calcari Grigi in the hangingwall are several hundred meters thick with synsedimentary fan-shape, whereas they are absent in the footwall, westward of the Badia Valley. The Mesozoic normal faults seem to be connected by transfer faults (Fig. 6). One transfer fault could be the eastward prolongation of the Passo Gardena Mesozoic strike-slip fault, which should continue throughout the Forcella Lavarella and the Fanes Valley. It is interesting to observe that the W-vergent Col Bechei overthrust undulates along the

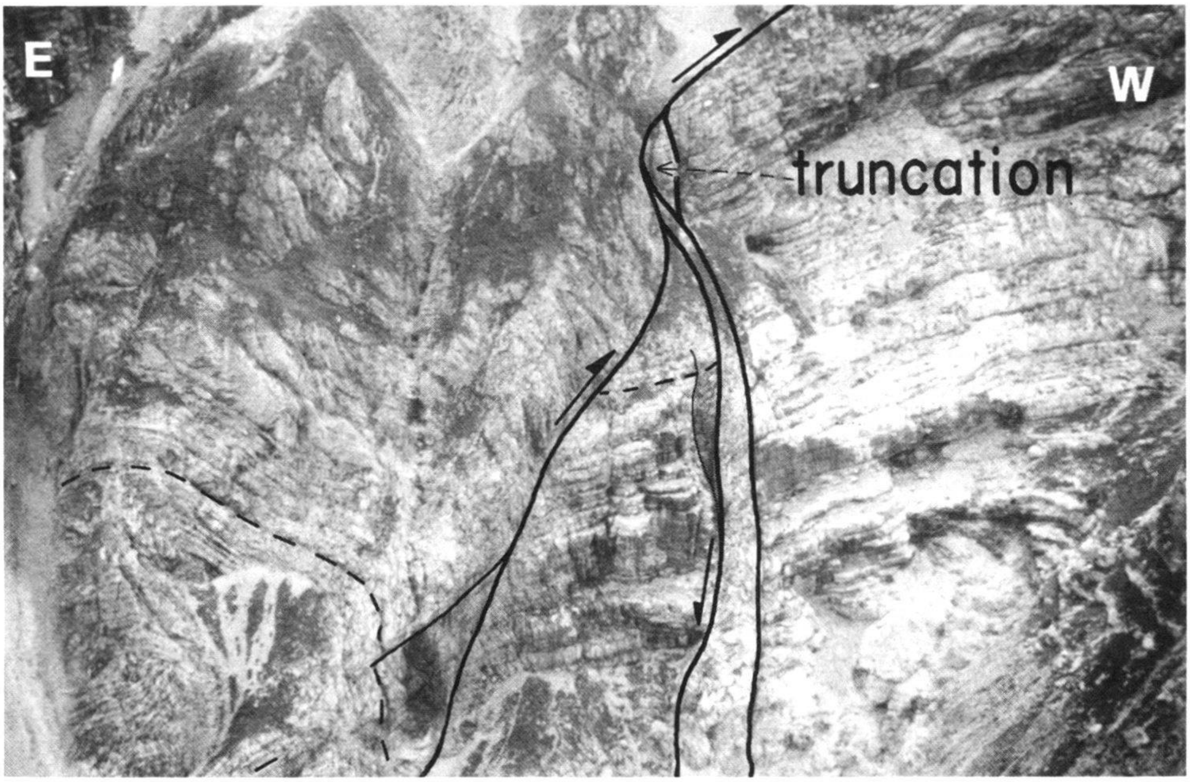


Fig. 5. Northern cliff of the Croda del Vallon Bianco, composed of Liassic Calcari Grigi. The W-vergent basal thrust plane cuts a pre-existing (Liassic-Cretaceous?) normal fault. Note the cataclastic fault rock.

Fanes Valley, showing sinistral transpression along the E-W trending valley where it connects the southern continuation at the Croda del Vallon Bianco. In other words, the Paleogene W-vergent thrust plane shows frontal, oblique or lateral ramp geometry as a result of its interaction with inherited features, such as normal or strike-slip faults, variations in thicknesses of the sedimentary cover, etc. (Fig. 6). For instance, an interpretation is that the ramp of the WSW-vergent Col Bechei thrust was developed close to a pre-existing normal fault whose footwall acted as a buttress. The geometry of the Croda del Vallon Bianco structure can also only be explained by assuming pre-existing normal faults which were cut and/or inverted during the "Dinaric" compression. In fact, the overthrusting of younger rocks (i.e. Cretaceous marls) onto older ones (i.e. Jurassic limestone) is explicable only if the Cretaceous rocks were structurally deeper before the compression. The WSW-vergent Col Bechei thrust rises southwards along strike through oblique and lateral ramps to the higher structural position of the Tofane klippen (not contained in Fig. 2).

Neogene tectonics is represented by the S-vergent thrusts and folds which deform the Monte Parei Conglomerate. Two main S-vergent thrusts crop out in the Col Bechei area (Figs. 3 and 4). The upper one dips steeper (40°–60° decreasing in the upper flat) probably due to tilting of the hangingwall as the deeper and younger thrust (25°–40°, in the frontal ramp and 40°–60° in the oblique ramp) developed. The overthrusts undulate in shape, with frequent oblique ramps generating en-échelon folds (Fig. 3). These folds decrease their wavelengths and increase their amplitudes toward the fault plane,

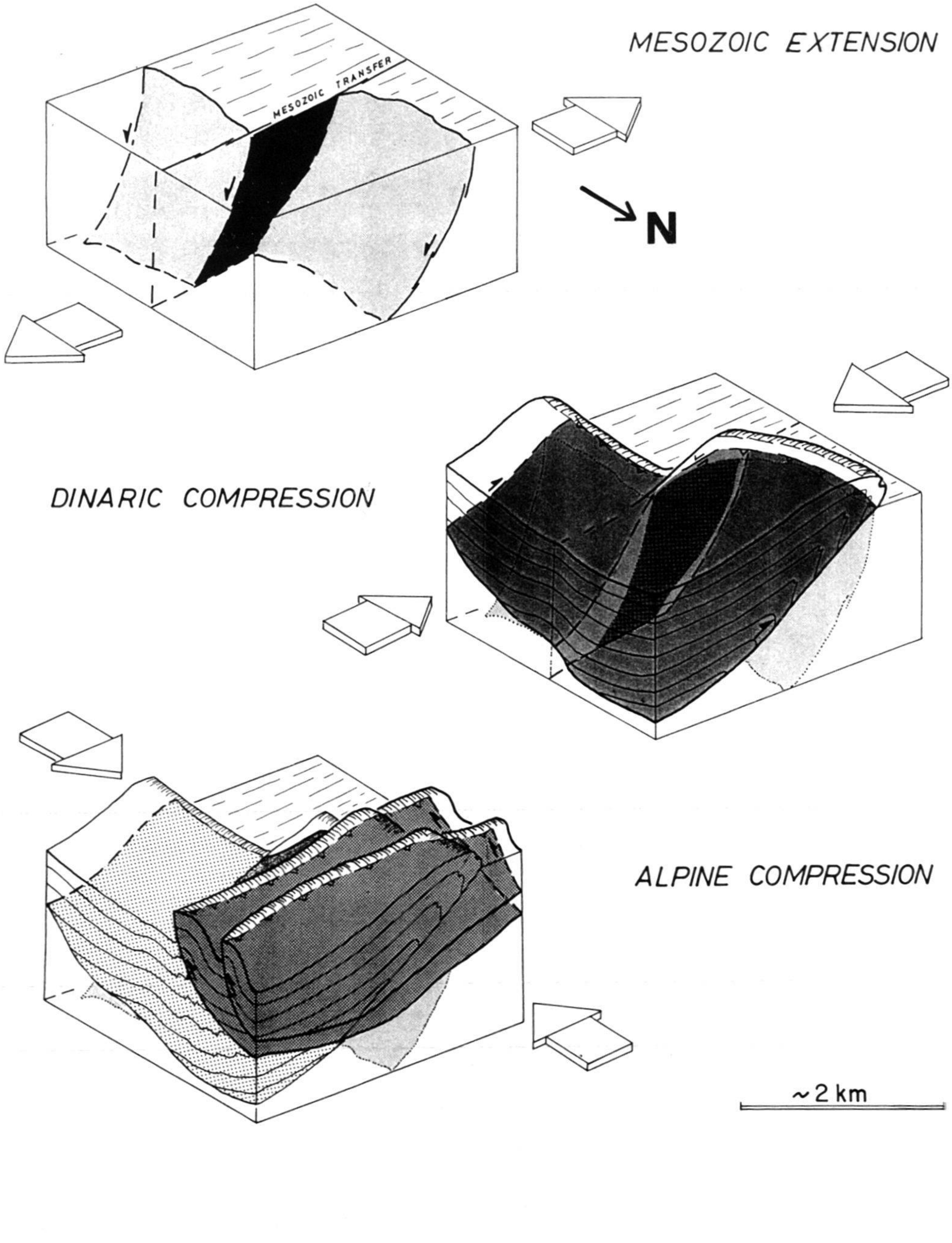


Fig. 6. Interpretative block-diagram of the polyphase tectonic evolution of the Col Bechei area with view from the northeast.

and flexural slip sometimes degenerates into small thrusts with typical ramp-flat trajectories and blind geometries (fault-bend folds and fault-propagation folds).

As stated before, the SSE-vergent structures overprint the earlier Mesozoic normal faults and, particularly, the WSW-vergent "Dinaric" compressive features (Fig. 6). This produced complicated interference patterns, such as that outcropping in the southern cliff of the Col Bechei (Fig. 3) where the W-vergent tight fold was cut by these younger thrusts and transported southwards. A Neogene, subvertical, N40°W trending dextral strike-slip fault, cropping out at the Passo di Limo, cuts the entire structure and represents the dextral lateral ramp of the upper S-vergent overthrust (n. 2 of Fig. 3) of the Col Bechei. Thrust n. 3 of Fig. 3 moves westward across Forcella Lavarella and Passo Gardena.

No convincing evidence for an earlier, "Eoalpine", tectonic phase has been found in the area. The presence of the Cretaceous Ra Stua Flysch, however, may suggest an advancing thrust belt further to the north. The Dolomites would then represent the foreland of this Eoalpine deformation.

Concluding remarks

The Col Bechei structure may be considered an example of polyphase orthogonal tectonics in a brittle regime. A schematic three dimensional kinematic reconstruction is proposed as Fig. 6. The present structural grain is due to the overlap of different compressive tectonic phases, WSW-vergent Dinaric (Paleogene in age) and SSE-vergent Southalpine (Neogene in age), and developed in a sedimentary cover previously affected by the Mesozoic tensional or transtensional faulting. In particular the lateral variations of the compressive structures are considered to be due to the influence of the inherited Mesozoic features.

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