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Northern Combin zone complex-Dent Blanche nappe contact: extension within the convergent Alpine belt

By *Gilles H. Wust*[1] and *David S. Silverberg*[2]

Abstract

The movement zone juxtaposing the Penninic Combin Zone Complex (CZC) and the Austroalpine Dent Blanche nappe (DBN) in the western Swiss Alps exhibits four contact types.

The first type is ductile and has been subsequently deformed. It therefore corresponds to the "basal thrust". The three other contact types are ductile to cataclastic overprinting all previously deformed structures. Their kinematic indicators reveal a sense of movement corresponding to normal faults. The DBN hangingwall is down dropped towards the south-east.

The varied nature of the contact resulting from the existence of the late Alpine normal faulting event, clarifies the following:

– the variation of the contact strike,
– the inconsistancy and diachroneity of the deformation sequences along the fault,
– the interplay between the contact strike and the surrounding lithologies,
– the difficulty to correlate incomplete or truncated stratigraphic sequences.

Keywords: Extensional tectonics, polyphase deformation, microfabrics, Penninic nappes, Austroalpine nappes.

Résumé

Le contact nord séparant le complexe ophiolitique Pennique de la Zone du Combin (CZC) et la Nappe Austroalpine de la Dent Blanche (DBN) présente une nature très variable. Quatre types de contact ont été différenciés.

Les contacts du premier type, qui sont ductiles et ont été déformés ultérieurement, correspondent au «chevauchement basal». Les trois autres types de contact sont ductiles à cataclastiques mais transposent toutes les structures précédentes. Tous les indicateurs cinématiques observés montrent un réglage parfait qui résulte d'une phase de déformation extensive, entraînant l'affaissement du compartiment supérieur (DBN) en direction du sud-est.

L'existence d'un contact dont la nature variable résulte de l'interaction de failles normales tardives avec le «chevauchement basal» permet d'expliquer:

– les variations d'orientation du contact,
– l'observation de phases de déformation contradictoires et diachrone le long du contact,
– l'interaction entre le contact et les lithologies environnantes,
– la corrélation difficile de séquences stratigraphiques incomplètes ou tronquées.

1. Tectonic setting

The field study area is located in the south western part of the Swiss Alps. Figure 1 presents a simplified regional tectonic map. The two crystalline basement massifs of the Mont-Blanc (west) and of the Aar (east) outcrop north of the Rhône Valley. These massifs are overthrust from the south by the Helvetic Calcareous nappe complex. South of the Helvetic Nappes lies the large Piemont zone which is subdivided into a series of various tectonic units (ESCHER, 1988). The Com-

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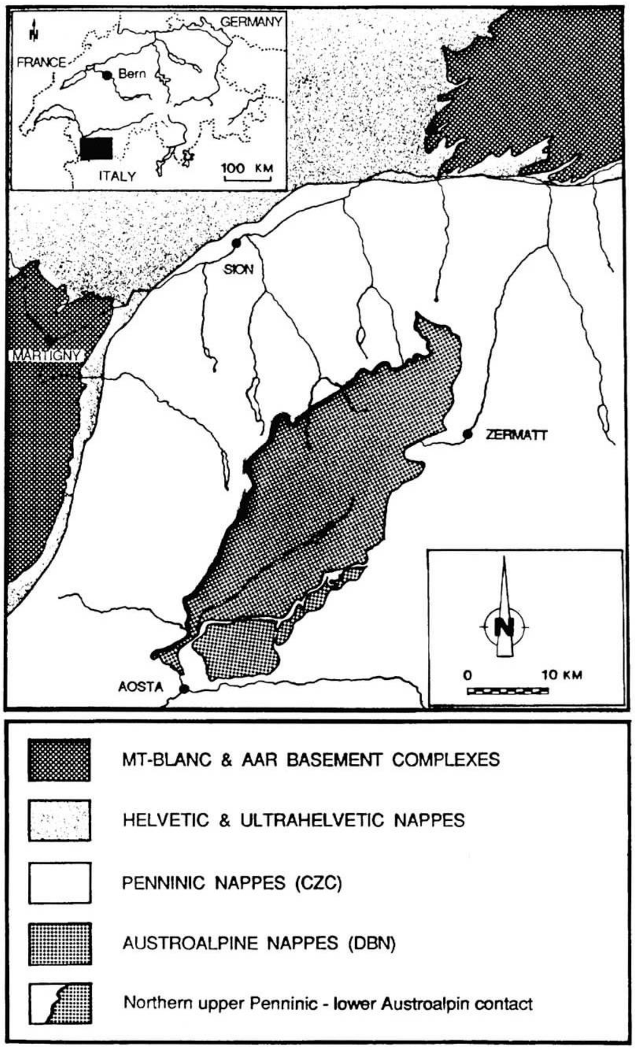

Fig. 1 Simplified tectonic map of the western Swiss Alps.

der greenschist facies conditions, activates normal faults (SILVERBERG and WUST, 1986, WUST and SILVERBERG, 1987) that clearly offset the three previous deformation stages (D1, D2, D3). This study reveals that an important section of the contact that presently separates the CZC from the DBN is related to a late Alpine extensive mode.

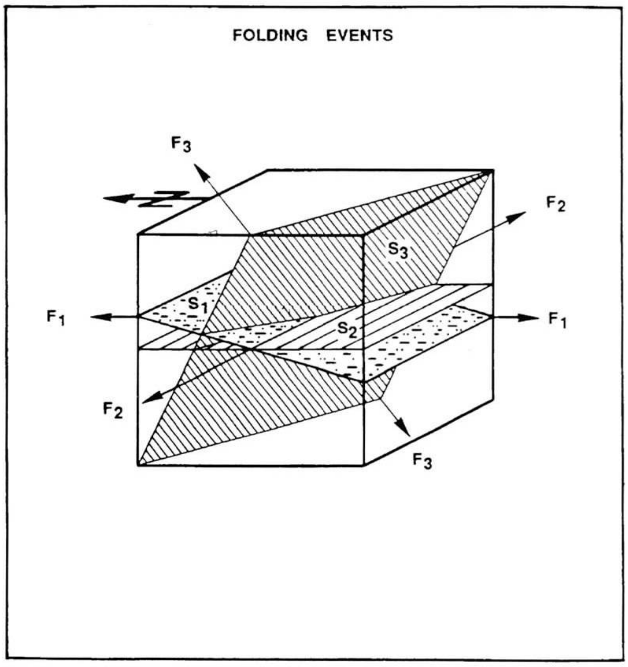

Fig. 2 Block diagram representing the three compressional deformation phases D1, D2 and D3. It shows the general orientation of the S1, S2, S3 foliation planes and F1, F2, F3 fold axes.

bin zone complex (CZC) (upper Penninic nappes) is composed of calc-schists (schistes lustrés), metapelites and a large portion of metabasites representing an almost complete ophiolitic series. The Dent Blanche nappe (DBN) is the lower portion of the Austroalpine domain. It is composed of orthogneisses of predominantly granitoid composition. Despite lithological variations, CZC and DBN display a relatively similar tectonometamorphic evolution (LE GOFF et al., 1986, BALLEVRE et al., 1986). A previous blueschist facies metamorphic assemblage, possibly related to a cretaceous subduction or underplating event, has been transposed into and overprinted by a polyphase greenschist facies dynamo-thermal metamorphism. An analysis of the deformation differentiates three events D1, D2, D3 taking place in a compressive environment (Fig. 2). A later event of extensive type, still un-

2. Petrology

2.1. COMBIN ZONE COMPLEX (CZC)

The lower CZC comprises a preophiolitic complex (SALIOT et al., 1980) of mesozoic continental deposits, breccias, polygenic dolomites, quartzites, limestones, marbles or dolomites (ESCHER, 1988; BEARTH, 1976; MARTHALER, 1984). The upper part of the CZC is a middle Jurassic to upper Cretaceous ophiolitic complex (KUNZ, 1988). It comprises an alternation of massive greenstones with various calcareous flysch, rich in foraminifa (MARTHALER, 1984). The metavolcanic rocks display a wide sequence ranging from prasinites to metagabbros and serpentinites (KUNZ, 1988; SARTORI, 1987). According to DAL PIAZ et al. (1981) these ocean floor basalts are comparable to other western Mediterranean ophiolites. The CZC has been intensely deformed by a strong greenschist facies metamorphic event that locally overprints relics of a former blueschist facies metamorphic event (LE GOFF et al., 1986).

2.2. DENT BLANCHE NAPPE (DBN)

The Dent Blanche nappe comprises from top to bottom: a mesozoic sedimentary cover, a granulitic basement (Valpelline series) and a granitoid complex (Arolla series). The Arolla series is the tectonic unit in direct contact with the CZC. Its lithology consists mostly of intercalations of para- and orthogneisses (granites to diorites) (MAZUREK, 1986; BALLEVRE et al., 1986) with rare mesozoic sediments (AYRTON et al., 1982). The age of the granitoid series is estimated to be Permo-Carboniferous (AYRTON et al., 1982; THELIN et AYRTON, 1983). Unlike other parts of the Austroalpine realm, no eclogitic metamorphic assemblages have been described in the DBN. Questionable lower blueschist to upper greenschist mineral assemblages have been observed (AYRTON et al., 1982; VOGLER, 1984; BALLEVRE et al., 1986). These higher pressure events are strongly overprinted by a later greenschist facies phase.

3. Regional deformation history

During the Alpine orogeny, both the CZC and the DBN recorded a relatively similar tectonometamorphic history. The general orientation of axial planes and fold axes of the first three major deformation events (D1, D2, D3) are schematically represented in block diagram (Fig. 2). A first deformation, D1, possibly related to the nappe emplacement, transposed a previous deformational event with associated blueschist facies metamorphism, leaving a strong metamorphic banding and a very penetrative S1 fabric. Refolded quartz rods (N-S) are interpreted as former hinges of tight isoclinal F1 folds. The D2 deformation is characterized by more open F2 folds and the development of a strong S2 axial planar crenulation cleavage. Locally a S2 cleavage is the dominant fabric and transposes S1. L2 actinolite and chlorite mineral lineations strike NNW-SSE. The D2 deformation phase postdates the nappe emplacement (WUST and SILVERBERG, 1987). The D2 deformational event that many authors relate to backfolding (MAZUREK, 1986; SAVARY, 1979; SARTORI, 1987; ESCHER, 1988; SAVARY and SCHNEIDER, 1983), affects the units in various ways. Deformation style is function of lithology. The competent DBN metagranitoids display open folds and tend to form wide basin and dome interference structures. The micaceous lithologies of the CZC favour interfolial slip deformation mechanisms that produce conjugate or single kink-bands. Ductile to ductile-brittle normal faults cross-cut every previous structure (D1, D2, D3). Kinematic indicators reveal a normal sense of shear corresponding to the down-dropping of the hanging wall to the south-east. Later minor brittle faulting systems (D5) crosscut all previous structures (D1, D2, D3 and D4). Figure 3 illustrates the main pre-faulting structures observed at 11 selected localities along the CZC-DBN contact. S2 and F3 are not plotted because this inhomogeneous deformation stage reflects lithological contrasts rather than characteristic geometric orientations. As observed in the field, the D4 faulting event crosscuts previous structures but does not offset them significantly.

4. Nature of the contact

4.1. FOUR MAJOR CONTACT TYPES

Four major types of contact have been observed on the northern CZC-DBN contact (Fig. 4). In absence of geochronological data, classical crosscutting relationships were used for classification: either the contact is folded by later deformations and predates D2, D3, D4 or it remains undeformed and postdates all previous structures (D1, D2, D3). One type of folded contact and three types of unfolded contacts are analysed in the following subsections. The appendix provides a list of the 11 selected localities with their corresponding contact types and minimal amount of data sets (N).

4.2. FOLDED CONTACT: A-TYPE CONTACT

A-type contact is folded and mylonitic. It is to be associated with less competent lithologies such as calcschists, pelitic schists or serpentinite. La Rousette area displays "flame structure" resulting from polyfolding (F2 and F3) of the original micaceous contact (Fig. 5a). Note that because of a strong D2 and D3 overprint, no sense of shear has been recognized. The type A contact was observed in the north-eastern part of the area. This type of outcrop corresponds to what many authors refer as the "basal thrust" of the DBN over the CZC (MAZUREK, 1986, SARTORI, 1987).

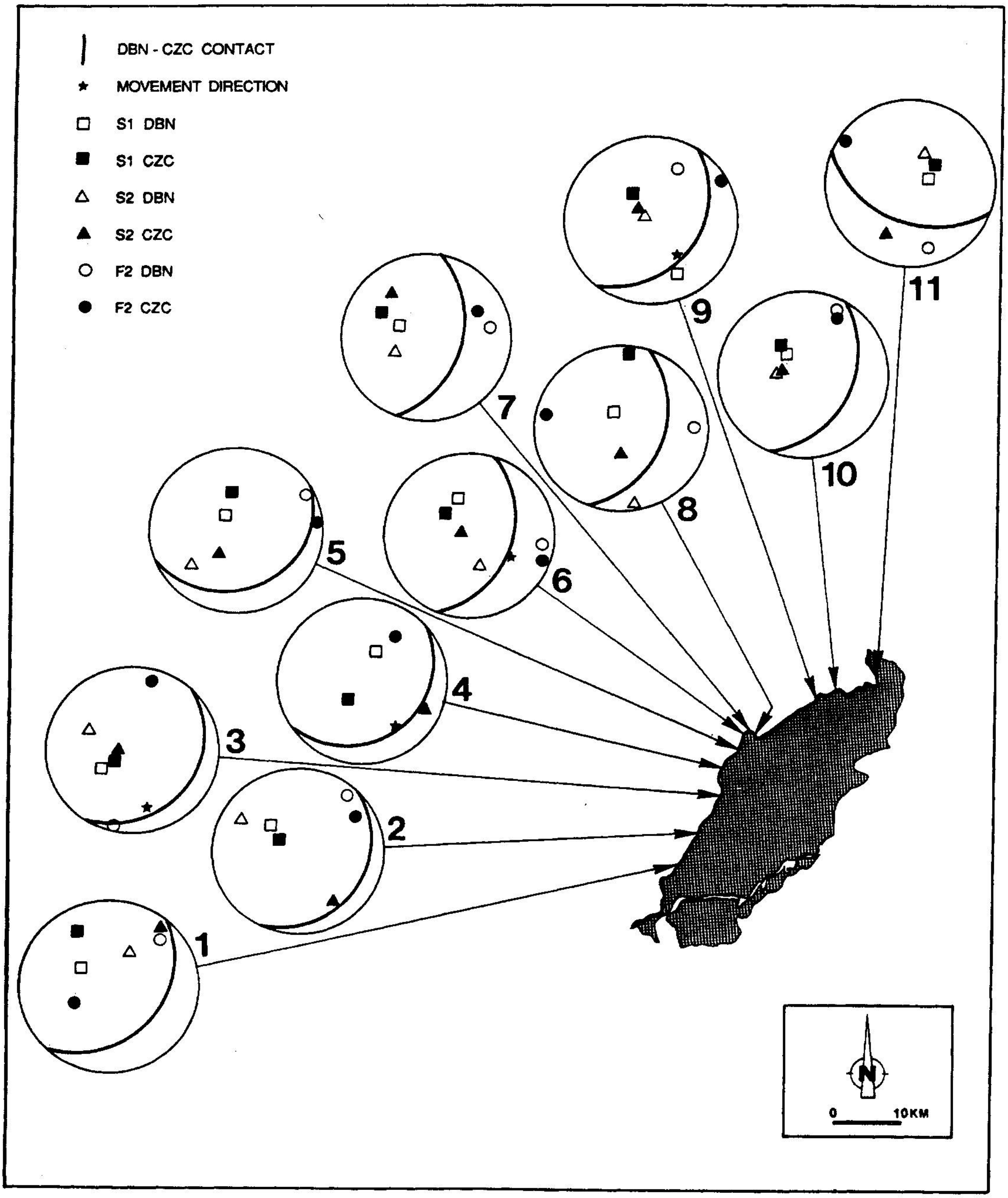

Fig. 3 Lower hemisphere, equal area plots of DBN-CZC contact orientation, S1, S2 foliations and F2 fold axes for CZC and DBN. The data are represented as mean values of measure sets for each of the 11 selected localities.

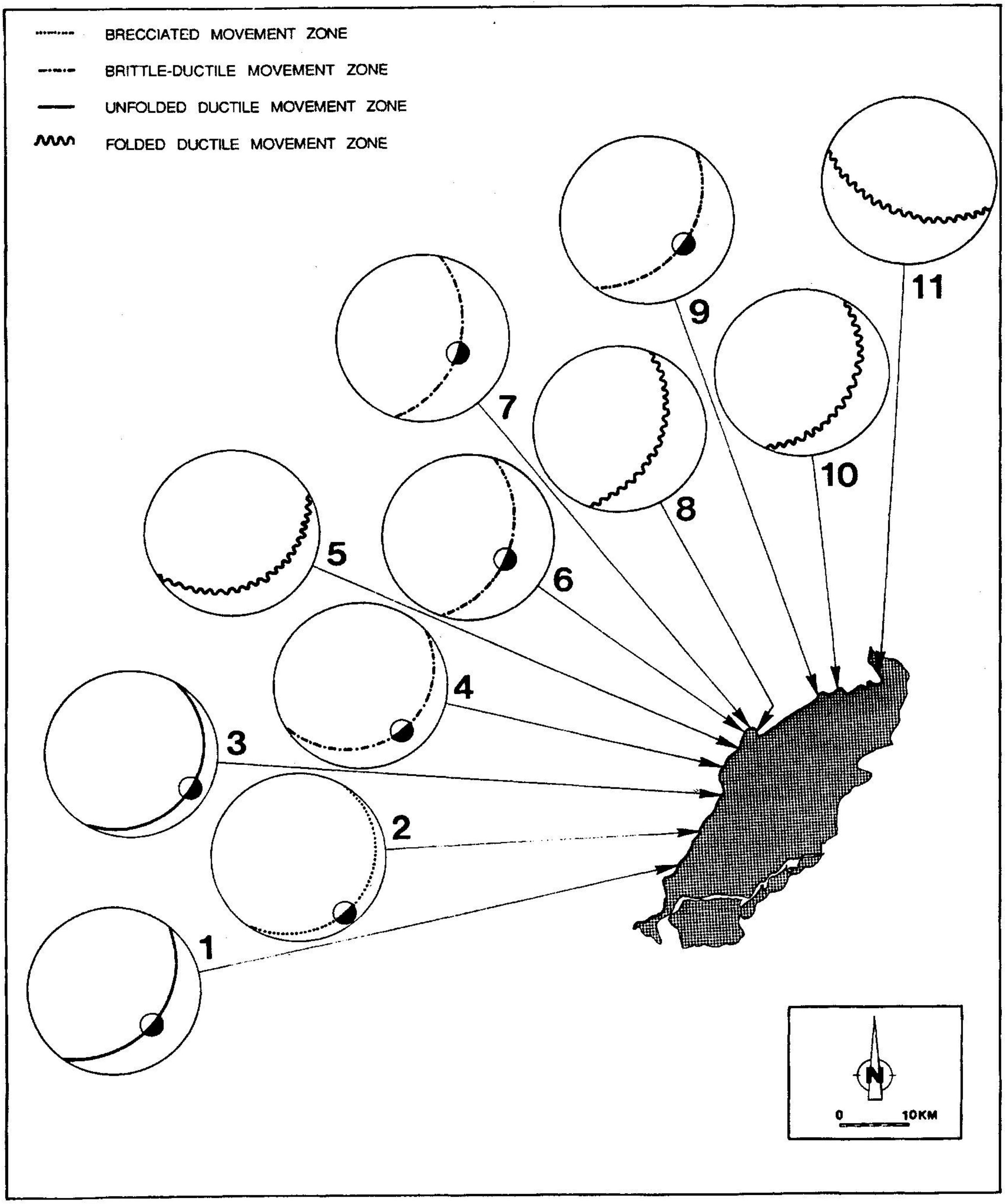

Fig. 4 Lower hemisphere, equal area plots of the orientation and nature of the contact types. The data are represented as mean values of measure sets for each of the 11 selected localities. The black half circle indicates the downthrown hanging wall.

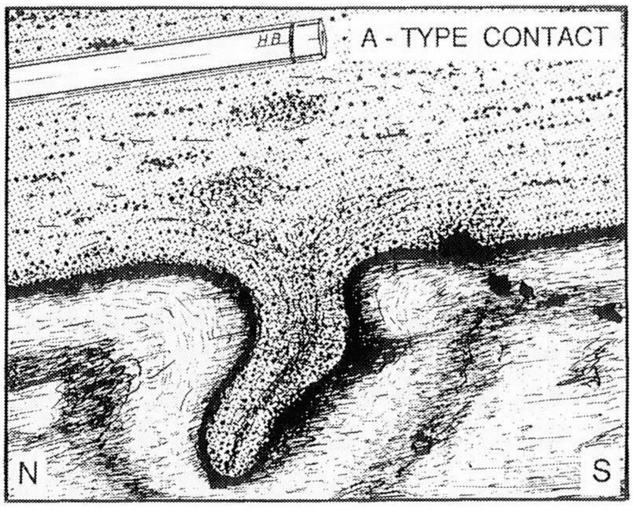

Fig. 5a A-Type contact (La Rousette area): The "basal thrust" juxtaposing the DBN gneisses (above) over the CZC schistes lustrés (below) displays polyphase deformation with associated D2 and D3 fabrics.

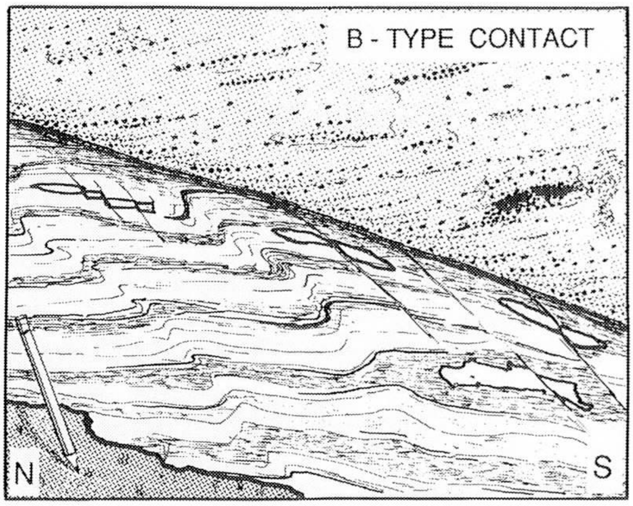

Fig. 5b B-Type contact (Glacier du Brenay area): The overlaying DBN gneisses are down dropped over the CZC schistes lustrés. Both sides of the contact show a strong mylonitization with deflection of D2 and D3 fabrics into the contact and associated shear bands. It indicates a dextral sense of shear.

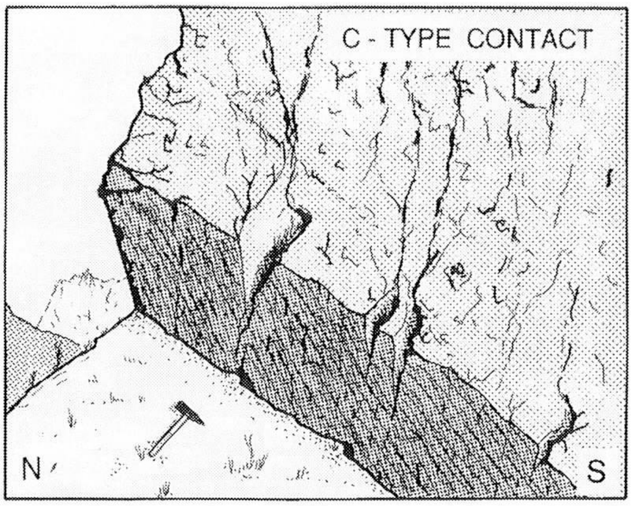

Fig. 5c C-Type contact (Mt Rouge area): A smooth and flat fault surface separates the undeformed DBN gneiss cliff (above) from the underlaying weathered CZC (in the scree). The fault plane shows a strong chloritic lineation (NW-SE).

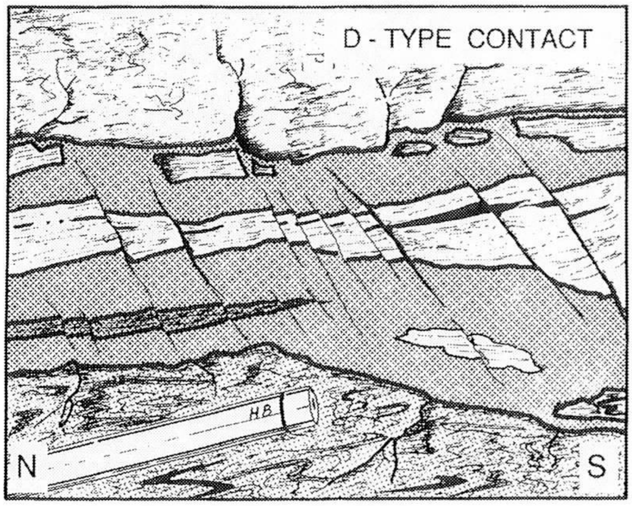

Fig. 5d D-Type contact (Mt Avril area): A brecciated tectonite surrounded by a phillitic matrix separates a massive greenstone (below) from a calcareous schist (above). This cataclastic fault splay indicates a dextral sense of shear.

4.3. UNFOLDED CONTACT: B-TYPE CONTACT

B-type contact is an undeformed mylonitic contact. It is a zone of high strain deformation whose nature varies from a meter thick mylonite to a 50m wide imbricated shear zone defined by lenticular lenses of Arolla series surrounded by a matrix of CZC calc-schists. D1, D2, D3 structures are extant adjacent to the shear zone but are not observed to crosscut this later fault. A typical example can be found in the Brenay glacier area (Fig. 5b). In the immediately underlaying CZC, the polyphase deformation sequence D1, D2 and D3 is readily observed. Close to the contact, S1, S2, S3 fabrics are deflected into the movement zone and become tangent to it. One can observe the development of discrete shear bands, at a slight angle (20–30°) to the fault zone whose concentration increases in proximity to the contact. A microstructural study of the later S-C fabric reveals that graphitic and phengitic foliations defining S-planes are transposed into C-planes. The quartz grains show undulatory extinction and deformation lamellae with a slight tendency to strain recovery. Quartz C-axis of silicious nodules have been measured on a texture goniometer (Fig. 6). It shows a very strong maximum corresponding to the axis of intermediate strain, with a minor asymmetry of the tails. It indicates a dextral sense of shear (top block to the south-east) and suggests a preferential slip on {1010} prisms-a, typical of intermediate temperature deformation (SCHMID and CASEY, 1986). The Arolla series of the DBN grades from undeformed into a strongly mylonitic orthogneiss. The deformation of the feldspars is brittle and exhibit a strong grain size reduction reflecting a probable high shear stress. Despite a lack of strain recovery and no significant crystallographic reorientation, quartz still deforms in a ductile way. Other genetically associated minor shear zones can be found close to the contact. The analysis of the kinematic indicators such as S-C fabric, discrete shear bands, mineral lineations, porphyroclast rotation, crystallographic deformation lamellae and preferred crystallographic orientation suggest a normal sense of shear in the fault zone with the upper block (DBN) moving down towards the south, south-east.

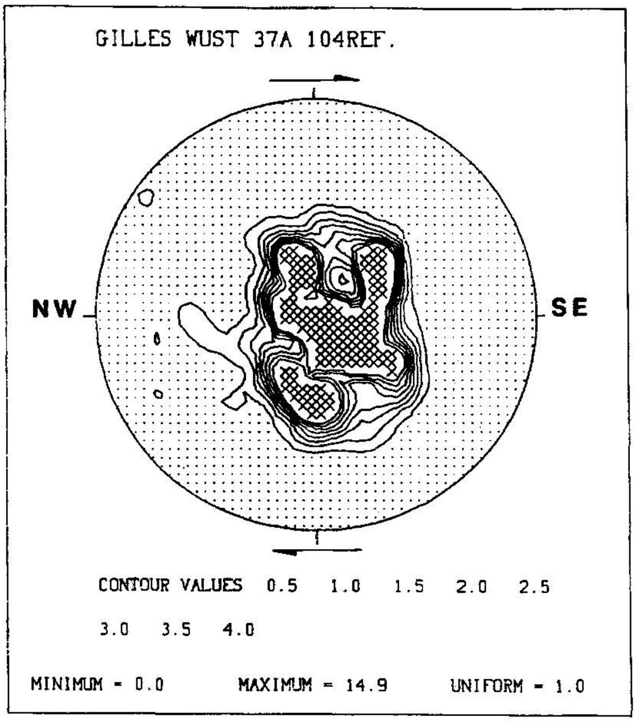

Fig. 6 Pole figure of quartz c-axes of CZC mylonitic quartz nodules (Brenay Glacier area). The contours are given in multiples of a uniform distribution. The lineation is NW-SE. It shows a preferential slip on {1010} prisim-a and an assymetry corresponding to a dextral sense of shear (top to the SE).

4.4. UNFOLDED CONTACT: C-TYPE CONTACT

The C-type contact is a narrow ductile-brittle contact. It can be differentiated from B-type by its shorter width (< 1m) and its hatcheted appearance (Fig. 5c). The fault plane is a clear-cut flat surface marked by strong chloritic mineral lineations dipping towards the south, south-east. The gneisses of the Arolla series located a few meters above the contact do not show persistent deformation features. The deformation appears to be restricted to this thin movement zone. Locally the movement zone varies from a single major fault zone into a disseminated complex of minor faults. Microfabric studies of the mylonitic fabric reveal the formation of small quartz grain ribbons and mica fish. The deformation of feldspathic porphyroclasts is brittle. The ductility grade of the deformation is a function of the mica content of the gneiss. Massive gneisses display a pseudo-cataclastic behaviour whereas micaceous gneisses are mylonitised. In general the deformation of the C-type contacts is strongly localized and hardly affects the surrounding rocks.

4.5. UNFOLDED CONTACT: D-TYPE CONTACT

D-type contact is always associated with heterogeneous lithologies: Calcareous micaceous schist, pyrite or chloritoid schists, fuchsitic tuffaceous philitic schists or serpentinites. The contact (Fig. 5d) is a calcareous brecciated tectonite chaotically juxtaposing a rather massive calcareous micaceous schist (top) with a polyfolded serpentinized green stone (bottom). This type of movement zone does not always correspond to the exact CZC-DBN contact. It is interpreted as a genetically associated splay of the main fault that took advantage of a more favourable lithology to progress.

4.6. COMMENTS ON THE DIFFERENT CONTACT TYPES

In summary we observe a consistency between the kinematic indicators and the shear sense criterions of all unfolded contact types (B, C, D) whether they are ductile, ductile-brittle or cataclastic. They all display a normal sense of shear and correspond to a down dropping of the hanging wall towards the south, south-east. A few problems related to the localization and the irregular behaviour of the contact zones should be mentioned:

– The hanging wall side of the contact that consists of more weathering resistant gneisses than the underlaying calc-schists, constantly outcrops. It is not always the case of the various CZC rock types.

– The highly variable and heterogeneous lithologies of the CZC strongly influences the rheologic behaviour of the movement zone. In order to minimalize the energy necessary to propagate, the fault tends to localize in the weakest medium, even if this does not correspond to the shortest path. Avoiding massive and competent metagabbro, metabasalt and ultrabasic bodies, the fault systematically evolves into a few splays of minor importance. Note that some of these splays were most probably brittlely reactivated during later and more recent alpine readjustments.

– When the deformation is very localized on the fault plane and restricted to a half meter band, most of the structural features on both parts of the movement zone appear to be continuous. If the fault does not outcrop clearly, its existence is difficult to assess.

5. Conclusions

The accretionary wedge model for collisional orogenic belts predicts the existence of concurrent extensive deformation regimes (PLATT, 1986). Such features have been reported by BURCHFIEL and ROYDEN (1985) in the Himalaya and by MANCKTELOW (1985); SELVERSTONE (1986) and BEHRMANN (1988), in the central and eastern Alps. This study reveals that an important section of the northern DBN-CZC contact is a normal fault. This produces evidence for extensional tectonics in the western Alps. However, in addition to their diverging direction of movement, the amount of displacement observed in the west is smaller in comparison to the large scale unroofing mechanisms observed by SELVERSTONE (1987) and MANCKTELOW (1985) in the east. In the studied area, both tectonic units (DBN and CZC) recorded a relatively similar structural evolution and no significant offsets of the metamorphic isogrades are to be seen or could be used to estimate the displacement along the fault. Heterogeneities in the CZC also prevent any evaluation of the fault throw based on marker horizons or other tectono-stratigraphic evidences. Other minor normal faults observed in the Penninic nappes (SAVARY, 1979; SILVERBERG et WUST, 1986; MAZUREK, 1986; WUST and SILVERBERG, 1987; ESCHER, 1988) suggest a regional late Alpine extensional deformation phase. The presence of this faults system, which should be detected on seismic profiles, could explain the following regional tectonometamorphic anomalies:

– The "basal thrust" does not seem to be folded by later events but the surrounding rock displays penetrative polyfolding structures (AYRTON and RAMSAY, 1974; BUCHER, 1985; MAZUREK, 1986).

– The CZC stratigraphy displays important regional variations. This is the result of normal faults that cut down section and partially behead the top of the CZC.

– The modification of the fault trace in La Rousette area corresponds to a change in the nature of the fault that can directly be related to a very high metabasite concentration.

The analysis of the nature and kinematic indicators of the CZC-DBN movement zone allows us to recognize four different contact types. This enables clarification of complex polyphase Alpine deformation history and stratigraphic correlations. This study stresses the importance of extensional tectonics in the late stages of the Alpine deformation in the western Swiss Alps.

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Dedication

This work is dedicated to the relationship of Bozon X and Bozon Y.

Appendix

List of Contact Types, Amount of Data Sets (N) and Locations:

1. B-type contact ($N > 20$): Mt Berrio
2. D-type contact ($N > 30$): Mt Avril
3. B-type contact ($N > 100$): Glacier du Brenay
4. C-type contact ($N > 30$): Col des Lies Roses
5. A-type contact ($N > 30$): Col de Cheillon
6. C-type contact ($N > 50$): Col de Riedmatten
7. C-type contact ($N > 30$): Aiguilles Rouges
8. A-type contact ($N > 40$): La Rousette
9. C-type contact ($N > 40$): Couronne de Bréona
10. A-type contact ($N > 30$): Moiry
11. A-type contact ($N > 20$): Tracuit

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