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Lithologic and tectonic environment of the Xigaze ophiolite (Yarlung Zangbo suture zone, Southern Tibet, China), and kinematics of its emplacement

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ABSTRACT

The Xigaze ophiolite (Yarlung Zangbo suture zone, Southern Tibet, China) has been mapped over 250 km from east to west with a few kilometers N–S width in the Xigaze area. It is stratigraphically overlained to the north (at its top) by the Xigaze Group unit which to the north stands in tectonic contact with a coarse detrital formation transgressive on the Gangdise plutonic unit. To the south the Xigaze ophiolite always stands in tectonic contact with sedimentary series, the contact zone being marked by a major tectonic breccia. The lithological and structural characteristics of the Xigaze Group unit, the ophiolite and associated sedimentary series (Liuqu conglomerate and Upper Jurassic red radiolarites) are described and a special attention is devoted to their relationships.

The kinematics of the thrusting of the ophiolite sheet is deduced from the analysis of the deformation in strongly deformed peridotites and in quartzites, respectively.

RÉSUMÉ

L'ophiolite de Xigaze (zone de suture du Yarlung Zangbo, Tibet méridional, Chine) a été cartographiée dans la région de Xigaze sur une distance est–ouest d'environ 250 km. Cette ophiolite est au nord (à son sommet) recouverte stratigraphiquement par le Groupe de Xigaze. Ce dernier est en contact tectonique subvertical dans sa partie septentrionale avec une formation sédimentaire détritique grossière reposant en discordance sur le complexe plutonique du Gangdise. Une brèche tectonique majeure marque le contact entre l'ophiolite de Xigaze et les séries sédimentaires situées plus au sud. Les caractères lithologiques et structuraux des différentes unités rencontrées au voisinage de l'ophiolite de Xigaze et leurs relations sont discutés.

La cinématique de la mise en place de l'ophiolite de Xigaze est déduite de l'analyse des directions et du sens de cisaillement dans des péridotites extrêmement déformées d'une part et dans des quartzites d'autre part.

Introduction

The Tibetan plateau can be divided into several E–W continental blocks bounded by major E–W sutures zones along which remnants of ophiolites have been preserved (CHANG & CHENG 1973, GANSSER 1977). The southernmost suture zone, called the Yarlung Zangbo suture zone constitutes the eastern continuation of the Indus suture

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known further west in Ladakh (FRANK et al. 1977, FUCHS 1977, ANDRIEUX et al. 1977, BASSOULLET et al. 1981 ...); it is geographically located just south of the Yarlung Zangbo river in the Xigaze area (CHANG et al. 1977, GANSSER 1977). This suture zone is probably Eocene and appears to be the youngest one (DEWEY & BIRD 1970, MOLNAR & TAPPONNIER 1975). It is marked by a nearly continuous belt of ophiolite which is the remnant of an ocean which separated the Indian continent to the south from the Lhasa block to the north. The main lithological and structural characteristics of the suture zone have been previously described and mapped by chinese geologists (CHANG & CHENG 1973, Geological map at 1:1500000 scale) and more recently by foreign geologists (BALLY et al. 1980, SHACKLETON 1981, TAPPONNIER et al. 1981, NICOLAS et al. 1981, BURG 1983, GIRARDEAU et al. 1984).

In the Xigaze area, one meets, from north to south several major distinct units: the Gangdise plutonic unit, the Xigaze Group unit, the Xigaze ophiolite and associated sedimentary series (Liuqu conglomerate and Upper Jurassic–Lower Cretaceous red radiolarites), and the Mesozoic Himalayan (Tethyan) flysch series (Fig. 1). This study will focus on the Xigaze Group, the ophiolite and associated sedimentary series, the main characteristics of other units having been already discussed (TAPPONNIER et al. 1981, BURG 1983). Our data have been obtained through three fieldwork expeditions (1980, 1981 and 1982) in the Xigaze area where a map extending over approximately 270 km in the E–W direction and 20 km in average in the N–S one, has been drawn at the 1:100000 scale (Fig. 2).

Lithological and structural characteristics of the different units

1. *The Xigaze Group unit*

The Xigaze Group unit outcrops between the Gangdise plutonic complex to the north and the ophiolite to the south over several hundreds of kilometers from east to west. It is constituted by a thick (6000–8000 m) flysch interpreted as a fore-arc basin deposit. This flysch was considered as transgressing to the north the Gangdise plutonic unit (BALLY et al. 1980, SHACKLETON 1981). The structure of the basin can be interpreted as a large symmetrical synclinorium formed during the late stages of shortening of the India–Eurasia collision during or after Eocene (SHACKLETON 1981, BURG 1983).

New data on the Xigaze Group unit show that this sedimentary complex can be divided into three distinct subunits (MARCOUX et al. 1983).

— The northern subunit is constituted by coarse-detrital sediments lying unconformably over the plutonic Gangdise unit. The series comprises coarse-polygenic and polymictic conglomerates containing plutonic (granodiorites, diorites and amphibolites) and volcanic (andesites, ignimbrites) rounded pebbles which can be a few decimeters in diameter. Some red sandstones, basaltic and ignimbritic lava flows and scarce coal and lacustrine limestone lenses are locally interbedded with the conglomeratic levels. This unit, quite similar to the Kailas conglomerate described by HEIM & GANSSER (1939), has been previously called the Qiuwu Formation by WU HAORUO et al. (1977). It is easily observable at the Dagzhuka trail bridge where it unconformably lies over metabasaltic rocks belonging to the Gangdise granodio-

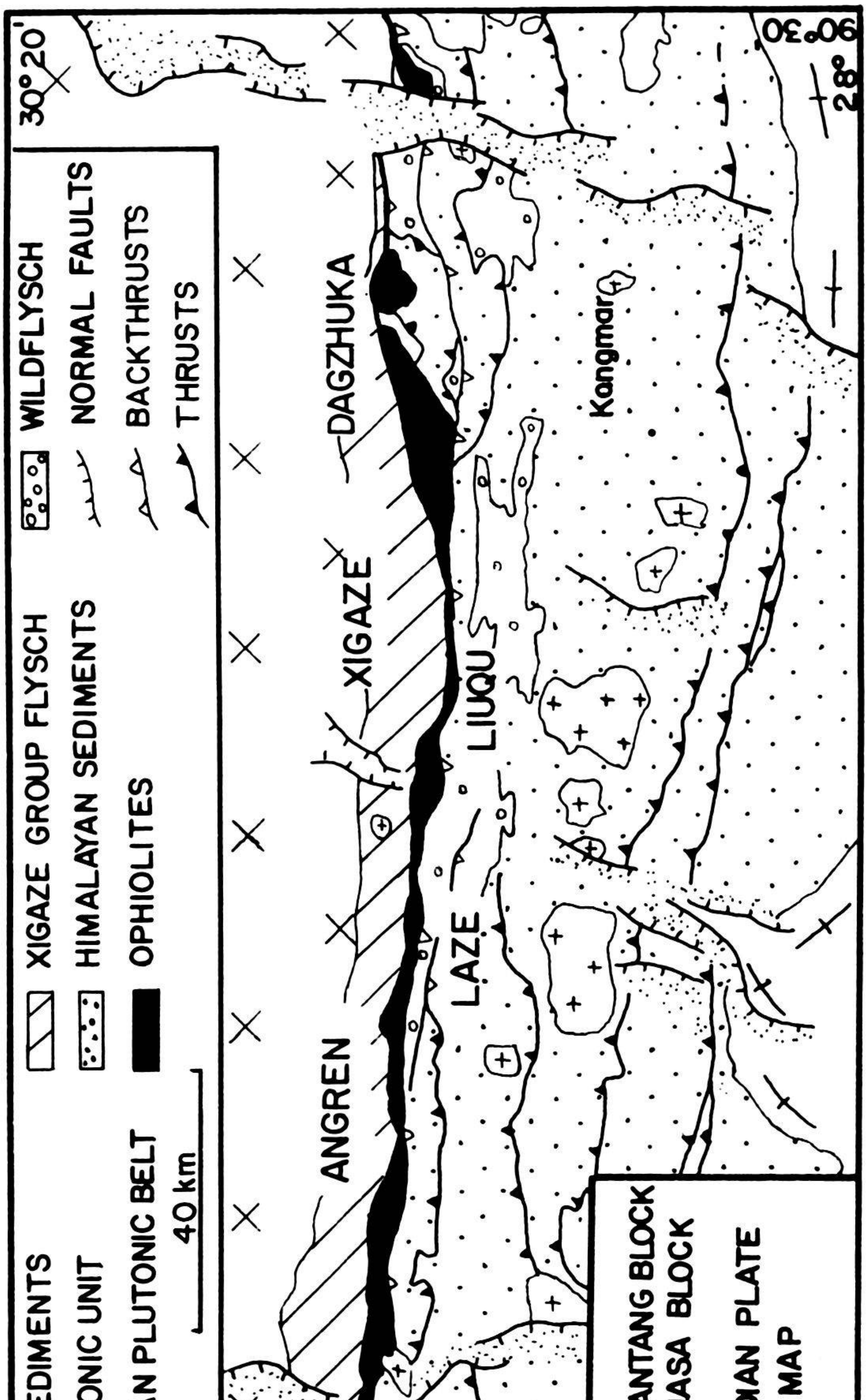


Fig. 1. Structural sketch map of Southern Tibet (from BURG 1983).

rite. To the south, this subunit is limited by a tectonic contact, nearly vertical or south-dipping as illustrated by Figure 3.

— The Xigaze Group sensu stricto begins by a few meters thick conglomerate composed of small sized (less than 10 cm) rounded pebbles of white quartzites, grey marbles and yellow sandstones. It is overlained by a thick rhythmic sequence of bedded sandstones, siltstones and slates which can be assigned to the Qiabulin, Sangzugang and Angren Formations of Wu Haoruo et al. (1977). The age of the lowest part of the Xigaze Group (northern part), is Upper Aptian–Albian as dated with microfauna and microflora including *orbitolinidae* from massive limestones interbedded at the base of the flysch which correspond to the Zangzugang Formation (Cherchi & Schroeder 1980, Wang Naiwen et al. 1983, Academia Sinica).

— The southern subunit is composed of radiolarites and bedded cherts lying in stratigraphic contact upon pillow lavas or lava flows which form the upper part of the ophiolitic sequence (Nicolas et al. 1981).
Although the contact between the Xigaze Group s.s., the radiolarites and the pillow lavas often is secondary tectonized by reverse or strike-slip fault zones (Xigaze, East Tiding and West Bainang), primary unfaulted contacts have been observed in many places such as in Dagzhuka, Polio and Cheujeon (Qunrang) areas (Fig. 4). At the contact with the radiolarites, the pillow lavas often show thin manganiferous encrustings. They are covered by 2 m of very fine-grained purple or green shales interbedded with rare thin calcareous or red radiolarite beds. This series is stratigraphically overlained by about 30 m of well-bedded white cherts, with individual beds approximately 30 cm thick. At their top, they grade into volcano-detritic and pelitic levels which can be assigned to the Xigaze Group s.s. flysch (Marcoux et al. 1982). We can therefore consider that the contact between these radiolarites and the Xigaze Group s.s. is a stratigraphic depositional contact.

Biostratigraphic datations on red radiolarian cherts sampled a few 10 cm above the pillow lavas at Cheujeon (Qunrang) section (Fig. 4) give an Upper Albian–Lower Cenomanian age (Marcoux et al. 1982). The same age is given from radiolarites interbedded with pillow lavas at Tiding section (Fig. 2).

To the east of Bainang, a several ten meters thick sedimentary breccia overlies the pillow lavas. The breccia consists mostly of angular volcanic blocks included within a volcanic cement. Some thin pelites, siltstones and radiolarites lenses are locally interbedded with the breccia.

2. *The ophiolite assemblage*

The Yarlung Zangbo ophiolite forms in the Xigaze area a sublinear and continuous belt over 250 km from east to west with a N–S width ranging from a few kilometers to 30 km (Fig. 2). It is cross-cut by N060° and N110° mostly dextral strike-slip faults and by nearly E–W south-dipping reverse faults (Nicolas et al. 1981, Girardeau et al. 1984). Whereas the northern contact of the ophiolite with the Xigaze Group s.s. unit is stratigraphic (as aforesaid), the southern one is always tectonic and is underlined by a major ophiolitic tectonic breccia.

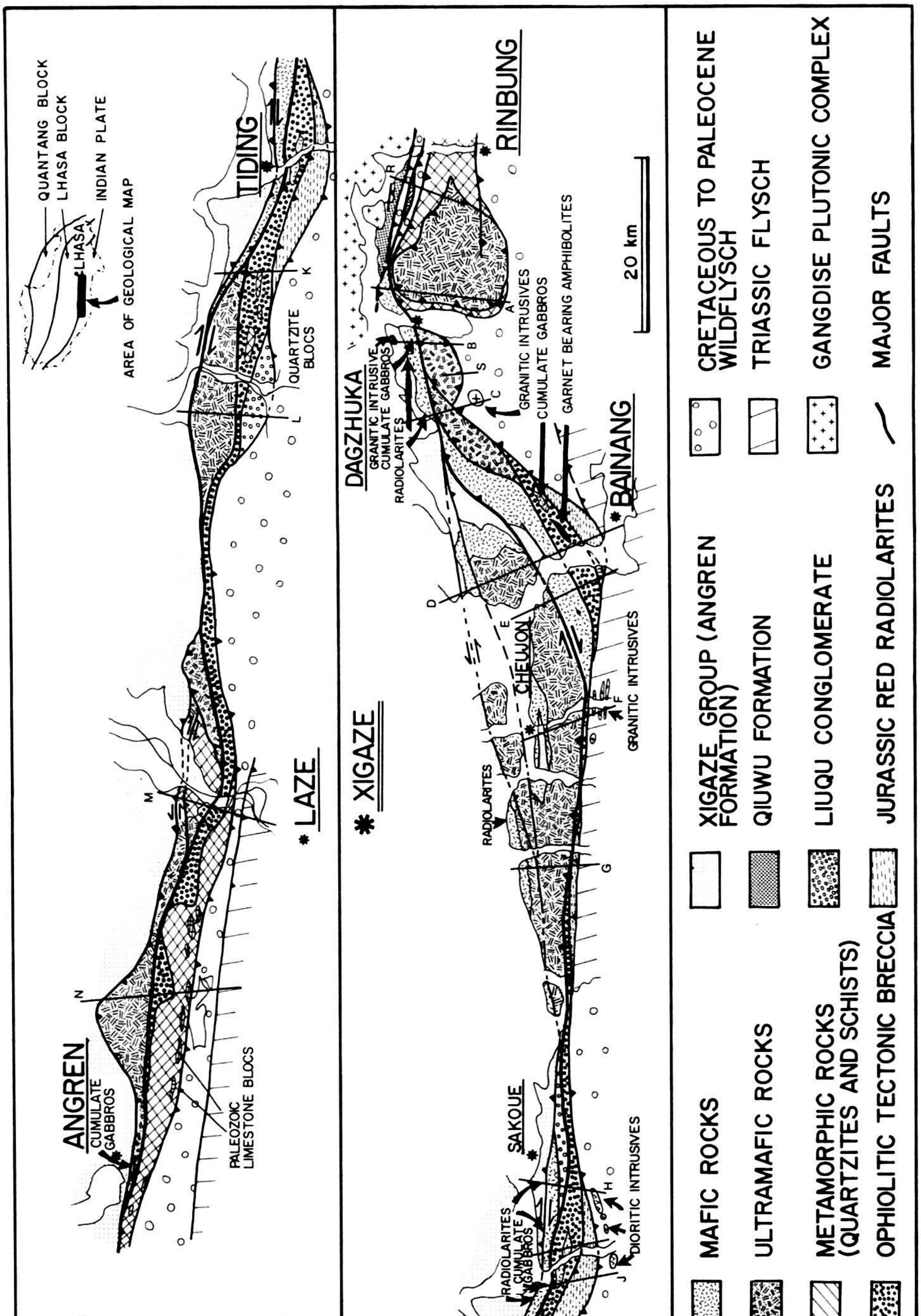


Fig. 2. Geological map of the Xigaze ophiolite between Dagzhuka and Angren.

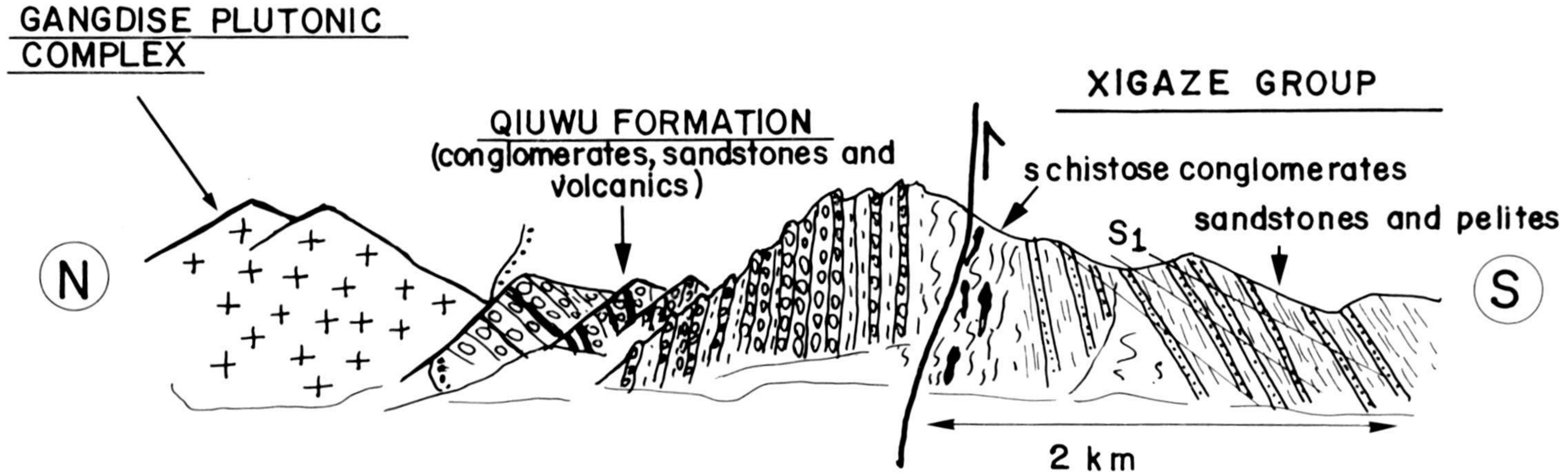


Fig. 3. N–S cross section located about 24 km north of Angren, showing the contact between the Gangdise plutonic complex, the Qiuwu Formation and the flysch of the Xigaze Group s. str.

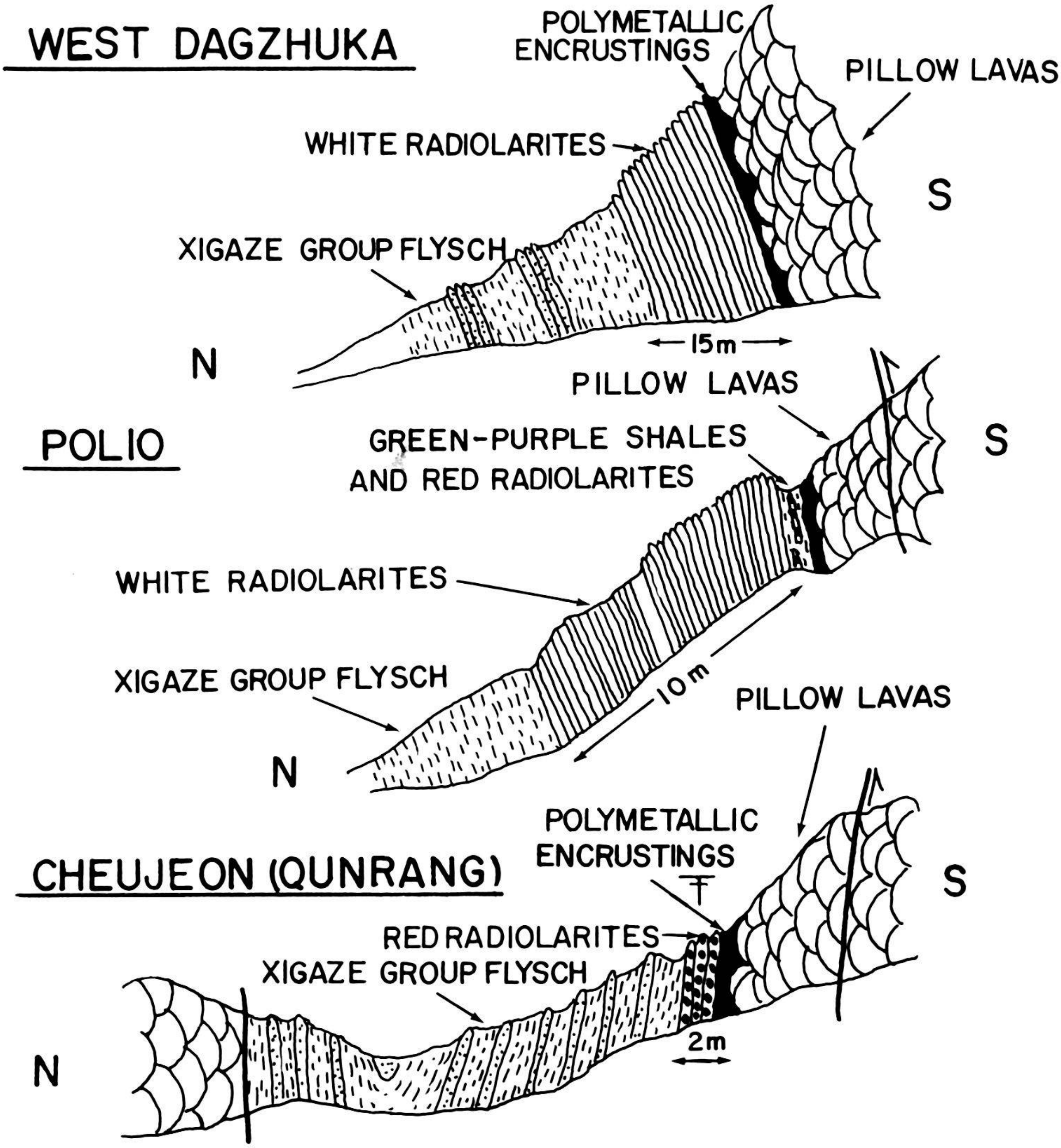


Fig. 4. N–S cross sections showing the contact between pillow lavas or lava flows on top of the ophiolitic sequence, and the flysch of the Xigaze Group s. str. These sections roughly correspond to the northern parts of sections B, C and F on Figure 2.

To the south of Dagzhuka section (Fig. 5A), the peridotites clearly form a klippe overlying a 300 m thick sole comprising from bottom to top low-grade metamorphic siliceous schists, with minor quartzites and ophicalcites. This sole tectonically lies over the Cretaceous to Paleocene wildflysch.

In the Bainang and Cheujeon areas (Fig. 2 and Fig. 5D, E, F), the ophiolite sheet forms large open folds with nearly ENE–WSW subhorizontal axes. The folds observed at Dagzhuka and Polio (Fig. 2, Fig. 5B, C) are overturned to the north and are accompanied by steeply south-dipping reverse faults parallel to their axial plane.

In the Sakoue, Tiding, Liuqu, Laze and Angren areas (Fig. 2, Fig. 5H–5N), the ophiolite assemblage has been strongly reduced in thickness because of the abundance of south-dipping backthrusts and of strike-slip faults. For instance, in the Liuqu–Tiding area, the mafic part of the sequence has been translated by roughly 25 km to the east along a major dextral strike-slip fault (Fig. 2).

In the Xigaze are (Fig. 2, Fig. 5G), the ophiolite sequence has only been tilted into a N060°, 60°NW attitude and seems to be complete.

Although strongly tectonized, the lithological relations within the ophiolite sequence as well as the orientation of the main magmatic and tectonic structures and microstructures, remain remarkably constant over the whole studied area (NICOLAS et al. 1981, GIRARDEAU et al., in press). This observations have lead to the conclusion that a complete ophiolitic sequence was locally preserved in the Xigaze massif and in the Dagzhuka and Polio massifs at least for the mafic part. The Xigaze ophiolite comprises from top to bottom (that is from north to south), thin marine sediments over basaltic pillow lavas or lava flows, dolerite sills and dikes with isotropic gabbro screens over an average thickness of 3 km, with locally layered gabbros, this sequence overlying about 1 km of residual serpentinized dunites and harzburgites and 4–6 km of fresh harzburgites locally rich in Cr diopside. One of the most important feature of this ophiolite is the occurrence of dolerites intrusives, both sills and dikes, throughout the whole ophiolite sequence from the peridotites up to the volcanics, which indicates a complex history for its genesis (GIRARDEAU et al., in press).

3. *The Upper Jurassic–Lower Cretaceous red radiolarites*

A thick unit comprising mostly red radiolarites, sometimes green or white, siliceous schists, a few tuffs and rare volcanic (calc-alkaline) sills, locally outcrops south of the ophiolite (Fig. 2). Though these rocks have undergone a very low-grade metamorphism (sericite–chlorite), they have provided Portlandian–Berriasian radiolarians (BALLY et al. 1980). They locally show large asymmetrical south-facing folds, with nearly E–W subhorizontal axes and without cleavage (Bainang section, Fig. 5D). In some places (Tiding), tight isoclinal folds with subvertical axes have been observed. They are accompanied by a strong E–W steeply south-dipping schistosity parallel to their axial plane.

At Dagzhuka, Polio, Laze and at the east of Angren (Fig. 2 and Fig. 5A, C, M, N), these rocks show a strong penetrative deformation in the greenschist metamorphic facies. This is easily observable in the East-Dagzhuka massif where they form a metamorphic sole beneath peridotites (Fig. 2, Fig. 5A, Fig. 6B). The metamorphic paragenesis in the more pelitic levels from the ophiolite sole is quartz, chlorite, epidotite and opaques. Development of posttectonic stilpnomelane rosettes is locally observed. South-facing chevron folds with nearly E–W subhorizontal axes locally refold the quartzites and schists foliation plane.

4. *The Liuqu conglomerate*

The Liuqu conglomerate always outcrops close to the ophiolite (Fig. 2, Fig. 5E, F, H, I, L and M). It is a coarse polygenic conglomerate comprising mainly rounded, 10–20 cm in diameter, pebbles of red radiolarites cemented by a red siliceous matrix. Some pebbles of dolerites and lavas have also been found in minor amounts within the conglomerate. A few thin sandstone beds are locally interbedded with the coarser conglomerate bancs.

In the western part of Laze section, the Liuqu conglomerate lies in unconformity upon low-grade metamorphic Upper-Jurassic radiolarites (Fig. 2, Fig. 5M). In the eastern part of the same section it unconformably lies over serpentinized peridotites. But it is, most of the time, tectonically squeezed within the ophiolite sequence due to the northward backthrusting (Fig. 2, Fig. 5H, I and M). The age of the Liuqu conglomerate is probably Oligo-Miocene (Academia Sinica 1980). The conglomerate is not metamorphic but shows open folds with subhorizontal E–W axes (Fig. 5H and I).

5. *The ophiolitic tectonic breccia*

The southern part of the ophiolitic sequence is, everywhere, bounded by a major tectonic breccia. It is a subcontinuous nearly E–W formation which can be up to 4 km thick as in the Liuqu, Bainang, Tiding or Laze areas (Fig. 2, Fig. 5). In this chaotic formation, blocks of different origins float in a serpentine matrix vertically sheared at low temperature. The blocks are derived from the ophiolite (harzburgites, gabbros, dolerites), the metamorphic sole (quartzites, schists, foliated garnet-bearing amphibolites) or from the sedimentary series (red Upper Jurassic–Lower Cretaceous red radiolarites, Liuqu conglomerate).

The blocks have various sizes ranging from several kilometers like quartzites and schists at Liuqu, dolerites at Tiding, cumulate gabbros at Bainang to several ten meters like the foliated amphibolites at Bainang and Dagzhuka, Upper Jurassic–Lower Cretaceous red radiolarites at Bainang and more generally to a few meters. Their extension is roughly E–W and their shape indicates a dextral sense of shear.

This tectonic breccia results from successive tectonic events. It is unlikely that it formed during the early stage of the obduction of the ophiolite as it corresponds to low-temperature conditions. The foliated garnet-bearing amphibolite blocks probably represent the remnants of a completely dismembered and eroded high-temperature metamorphic sole as found beneath many ophiolitic complexes and should be related to primary oceanic thrustings before obduction (Williams & Smyth 1973). The tectonic breccia may have formed during the tectonic emplacement of the ophiolite sheet onto the Himalayan series and could be then, contemporaneous with the deformation observed in the quartzites. But the presence of quartzites and Liuqu conglomerate blocks within the breccia indicates that it was still active during the episodes of backthrusting and strike-slip faulting. This is confirmed by the vertical and horizontal striations on slickensides.

6. *Late intrusives*

Late and undeformed plutonic rocks of alkaline to calc-alkaline affinities have been found in different units along the suture zone (Fig. 2). They display ophitic textures with plagioclase, green hornblende, magnetite and quartz. Diorite sills south of Tiding and Sakoue (Fig. 2, Fig. 5H and J) develop a low-temperature contact metamorphism in surrounding sedimentary rocks.

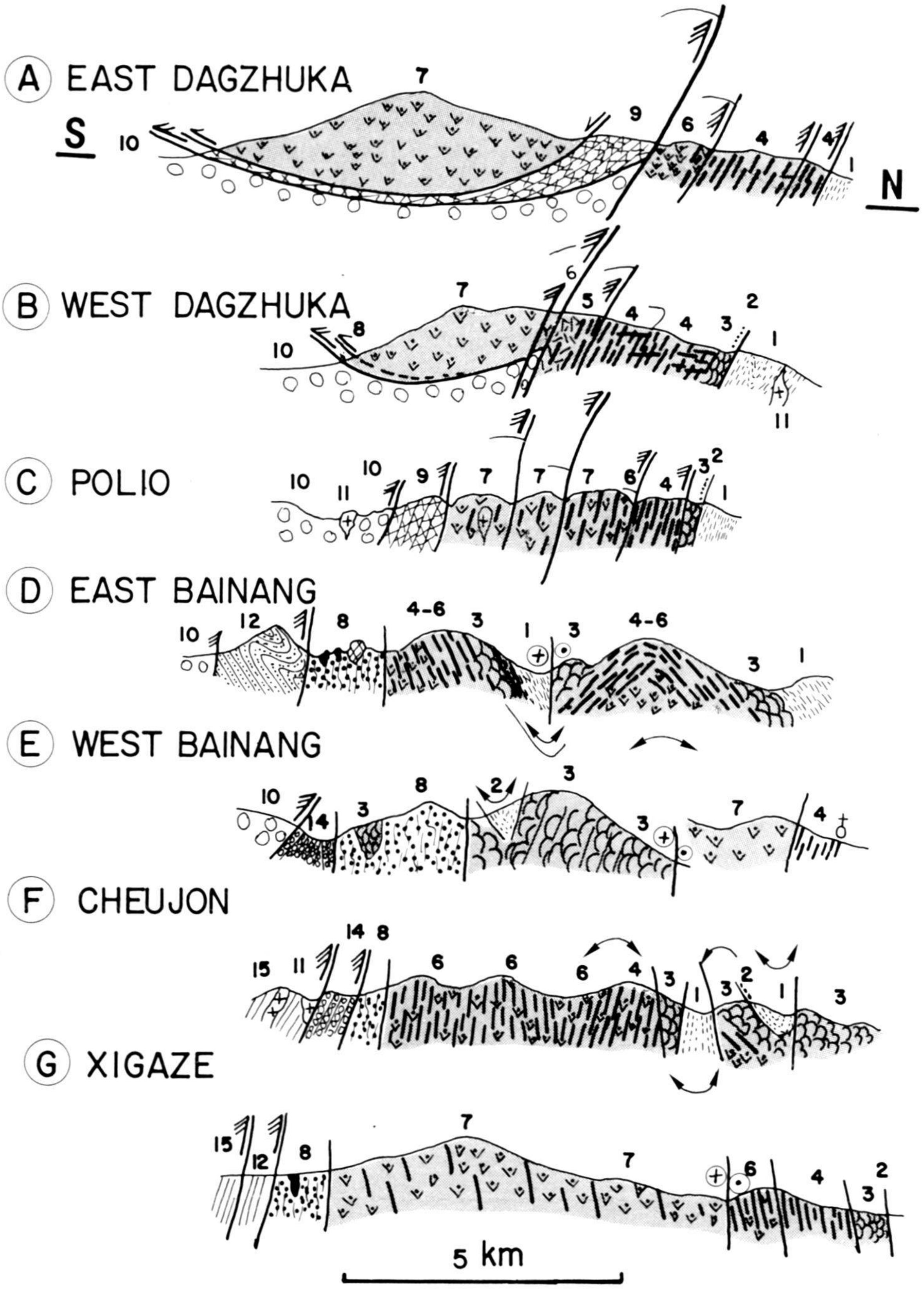
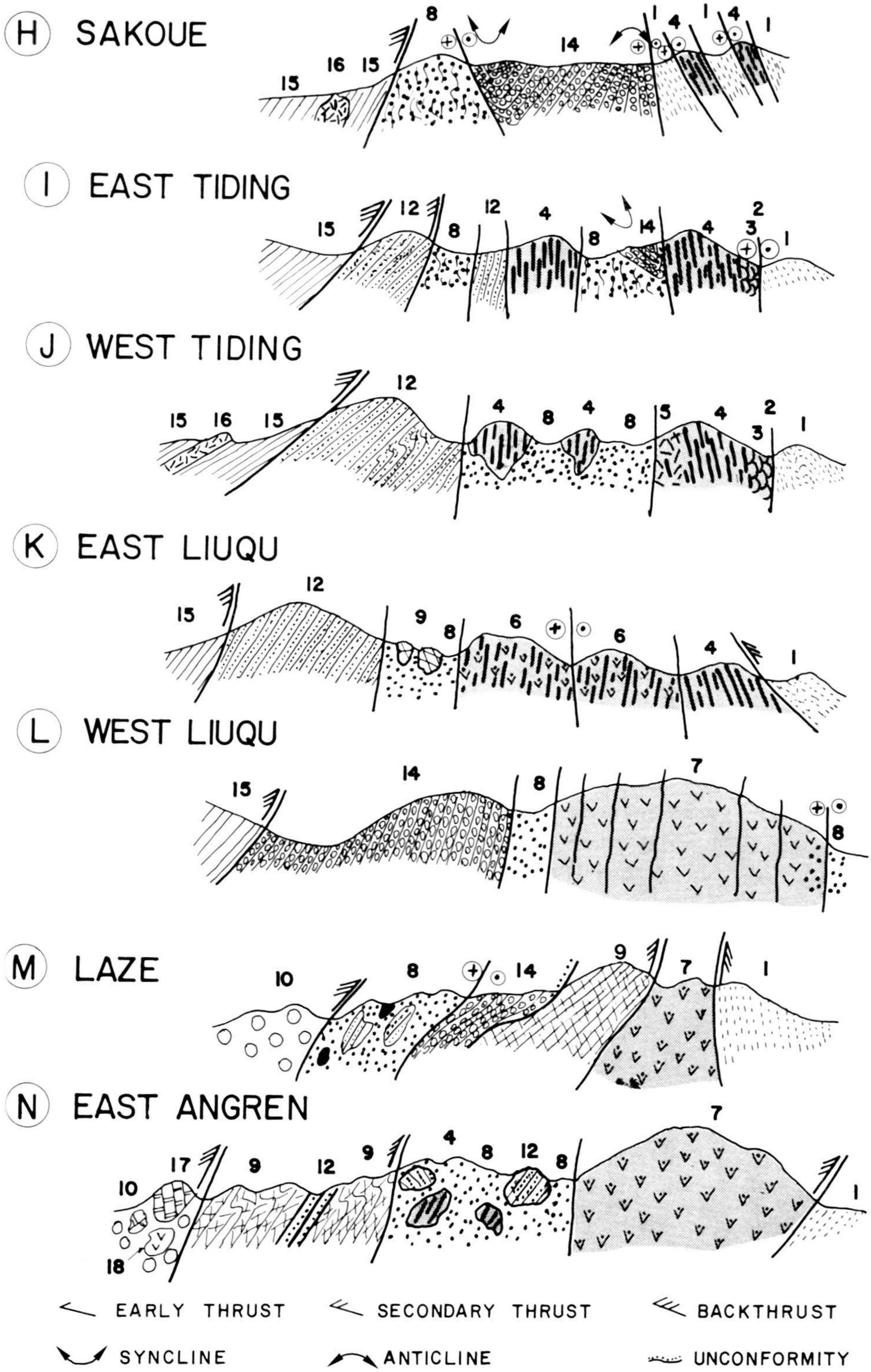


Fig. 5. Seriate sections across the Xigaze ophiolite (location of sections on Fig. 2). 1 = flysch of the Xigaze Group s. str.; 2 = radiolarites in stratigraphic contact with pillow lavas or lava flows; 3 = pillow lavas or lava flows; 4 = dolerite sills and dikes with gabbro screens; 5 = cumulate gabbros; 6 = dunites; 7 = Cr-diopside-bearing harzburgites; 8 = mylonitic peridotites; 9 = quartzites and schists; 10 = Cretaceous to Paleocene wild-flysch; 11 = alkaline to calc-alkaline late intrusives; 12 = Upper Jurassic red radiolarites; 14 = Liuqu conglomerate; 15 = Trias–Lias flysch; 16: calc-alkaline late intrusives; 17 = Paleozoic limestones blocks; 18 = volcanic blocks.


H SAKOUE
I EAST TIDING
J WEST TIDING
K EAST LIUQU
L WEST LIUQU
M LAZE
N EAST ANGREN
EARLY THRUST
SECONDARY THRUST
BACKTHRUST
SYNCLINE
ANTICLINE
UNCONFORMITY

South of Cheujeon (Fig. 2 and Fig. 5F), sills of hypocrystalline granites are intrusive in the Trias–Lias flysch. The granite was deformed in hot conditions and show phenocrysts of sodic and potassic feldspars, biotite, green hornblende and quartz in a microcrystalline matrix.

In the Dagzhuka and Polio areas (Fig. 2, Fig. 5B and C), a few granodioritic dikes are intrusive in the Xigaze Group flysch as well as in the Cretaceous to Paleocene wildflysch. These rocks are not deformed and show equant textures with abundant sodic plagioclase and minor green hornblende and quartz. No datations have yet been done on these rocks.

Discussion

1. *Kinematics of emplacement of the ophiolite*

The kinematics of emplacement of ophiolite complexes can be inferred through the analysis of shear direction and sense as well in strongly deformed peridotites (NICOLAS et al. 1980, GIRARDEAU & NICOLAS 1981, GIRARDEAU 1982) as in quartzites from metamorphic soles which often lie beneath ophiolite complexes (BOUDIER et al. 1983). The paleothrust plane attitude is given by the attitude of the foliation in the sheared rocks, the direction of thrusting by the direction of the sheared lineation and its sense through mineral preferred orientation data.

Deformations related to a primary and probably intraoceanic thrusting event have been found in the southern part of the West-Dagzhuka massif where mylonitic peridotites outcrop over a zone more than 300 m thick (Fig. 6A). In these peridotites, the primary foliation S1 has been completely transposed and the S′1 superimposed mylonitic foliation and associated L′1 stretched lineation L′1 are oriented at N005°, 80°W and N005°, 15°S in the field respectively (GIRARDEAU et al., in press).

In thin sections, the peridotites show fine-grained porphyroclastic to mylonitic structures (MERCIER & NICOLAS 1975). Porphyroclasts of olivine with tight substructures generally still persist. They have more or less recrystallized by subgrain rotation (see in NICOLAS & POIRIER 1975) into neoblasts 30–150 microns in size and also by grain boundary migration (see in NICOLAS & POIRIER 1976) into neoblasts a few microns in size (smallest neoblasts of Fig. 7).

The analysis of olivine orientation (Fig. 8) indicate that these rocks have been deformed in a rotational regime with a dominant (001) [100] slip system indicative of low to moderate temperature conditions (see in NICOLAS & POIRIER 1975). The stress estimated from the neoblast grain size using experimental calibrations for subgrain rotation (POST 1973, MERCIER et al. 1977, ROSS et al. 1980) would vary from about 850 to more than 1500 bars. The senses of shear indicate a southward movement of the overlying block relative to the underlying one.

To determine the paleo-attitude of the early thrusting event which has produced these low to moderate temperature-large stress deformations, two tectonic corrections must be applied to the field raw orientations, as the ophiolite sheet has first been folded and then has undergone an anticlockwise rotation of 90° during its emplacement (POZZI et al., in press). After corrections, the paleo-orientation of the thrust plane becomes N085°, 50°NW and the paleo-direction of thrusting N125°. Its sense was from north to south.

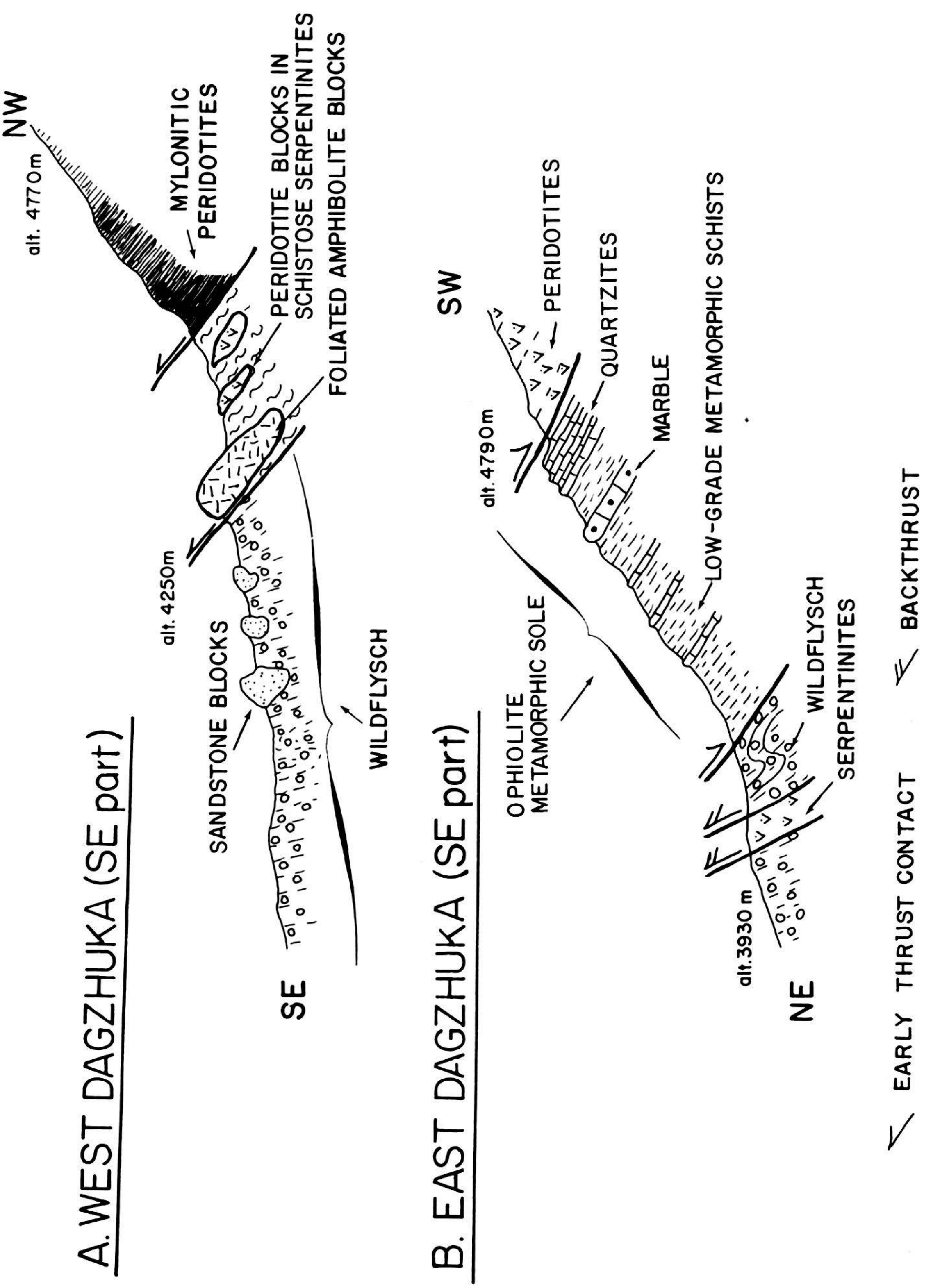


Fig.6. A: SE–NW section through the contact zone between mylonitic fresh peridotites and the wildflysch in the southern part of the West-Dagzhuka massif (line R on Fig. 2). B: NE–SW cross section through the Dagzhuka metamorphic sole (line S on Fig. 2).

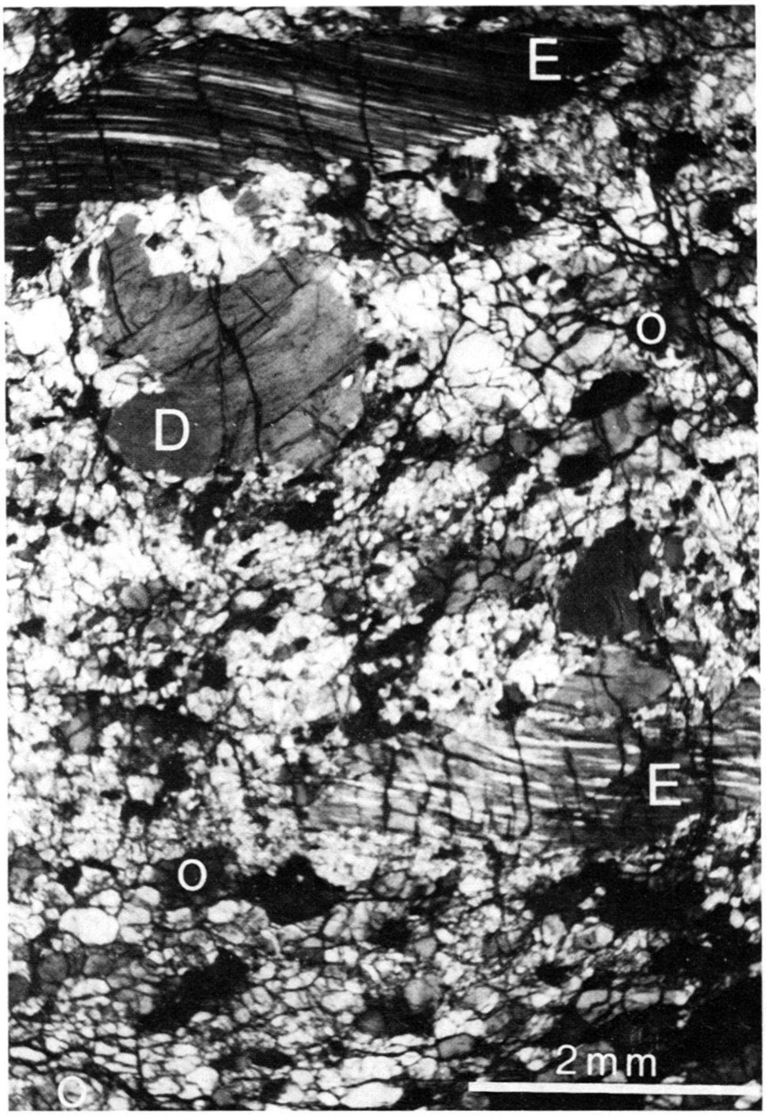


Fig. 7. Microphotograph of a mylonitic peridotite from the southern part of the West-Dagzhuka massif (see the bimodal olivine (O) neoblast size distribution and the stretching of enstatite porphyroclasts (E) along (100) planes subparallel to the superimposed S′1P foliation; D = diopside porphyroclast).

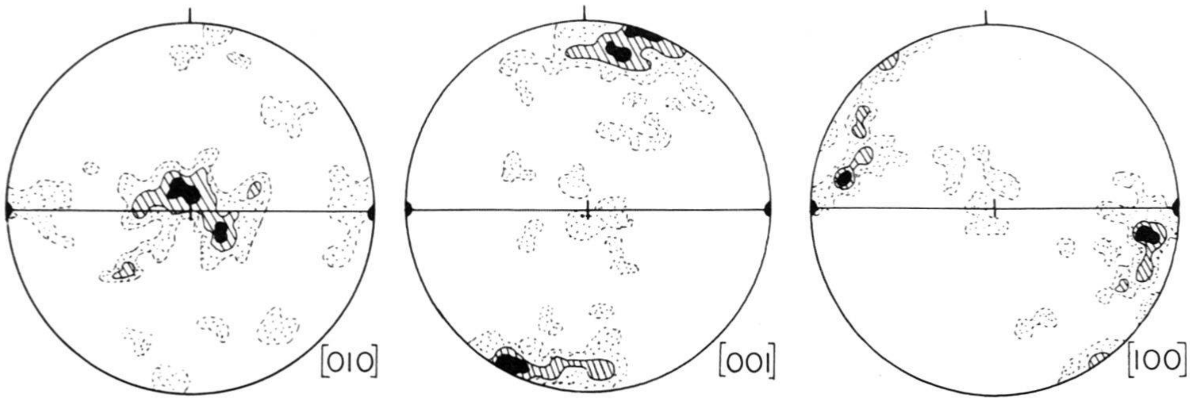


Fig. 8. Preferred orientation of olivine neoblasts in a fine-grained mylonitic harzburgite; 50 measurements, contours 8, 6, 4, 2%; structural reference system: foliation vertical E–W (solid line); lineation horizontal (solid dot).

As aforesaid, a 300 m thick sole comprising low-grade metamorphic siliceous schists with minor quartzites and ophicalcites, has been found beneath the East-Dagzhuka peridotites (Fig. 6B). These rocks represent metamorphosed and tectonized Upper Jurassic–Lower Cretaceous pelites and red radiolarites which generally outcrop just south of the ophiolite (Fig. 2).

At the contact zone with the ultramafics, the radiolarites have completely recrystallized into a fine-grained assemblage with a neoblast size a few microns in range (Fig. 9). They are strongly foliated with a nearly flat attitude and a N 145° stretching lineation. The foliation planes are cross-cut by late shear zones slightly oblique to them (a few degrees), and underlined by syntectonic chlorite recrystallization. The analysis of the shear sense through cross-polarizer with the method described by NICOLAS & POIRIER (1976), indicates a southward sense of shear. The shear sense along the late chlorite

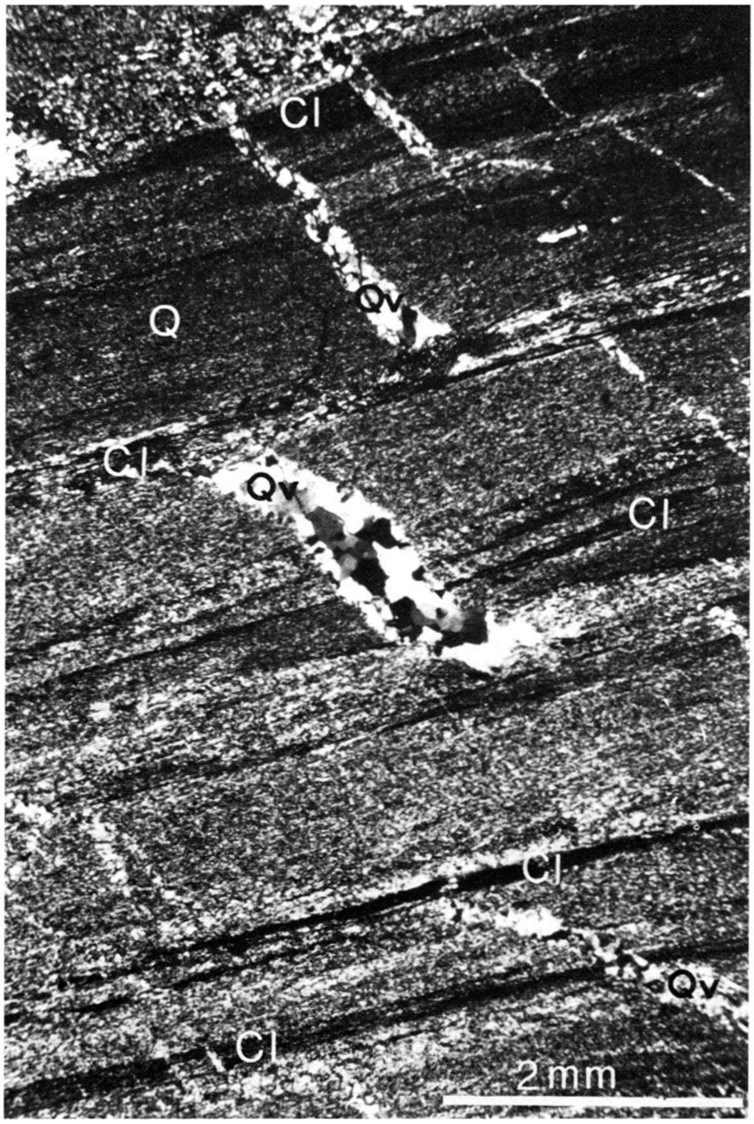


Fig. 9. Microphotograph of a mylonitic quartzite from the upper levels of the Dagzhuka metamorphic sole (Q = very fine-grained recrystallized quartz neoblasts; Cl = syntectonic chlorite in shear zones subparallel to the primary foliation; Qv = quartz vein).

bearing shear zones is also southward as indicated by the offset of quartz veins (Fig. 9). This indicates that the emplacement of the ophiolite occurs from north to south in a N 145° direction. This result is in good agreement with that obtained from the analysis of deformation structures in sedimentary series lying south of the ophiolite (BURG 1983). It is noteworthy that this later emplacement direction (not corrected), is roughly the same direction than that deduced after tectonic correction from the primary thrusting which produced the deformation of the peridotites.

2. *Conclusions*

Several important points about the relationships between the different units defined in the Yarlung Zangbo suture zone, in the Xigaze area, are now summarized.

1. The northern contact of the Xigaze Group flysch with the Qiuwu Formation transgressive to the north on the Gangdise plutonic unit, is tectonically marked by a major south-dipping reverse fault as previously observed (MARCOUX et al. 1983, BURG 1983). It is likely that the Qiuwu Formation conceals a major tectonic contact located south of the Gangdise plutonic unit. Although no serpentine has been found north of the Xigaze Group, some metabasic rocks interpreted as meta-ophiolitic rocks, locally occur as xenoliths in the southern part of the Gangdise plutonic unit (PROUST et al. 1983, BURG 1983). They are conformably overlain by the Qiuwu Formation at the Dagzhuka trail bridge.

2. The contact between the radiolarites from the base of the Xigaze Group and the pillow lavas from the top of the ophiolitic sequence is a stratigraphic contact as previously described by NICOLAS et al. (1981). It is often faulted because of the late northward backthrusting and strike-slip faulting.

3. The southern contact of the ophiolite with sedimentary series is always tectonic and marked by a major tectonic breccia locally comprising high-temperature metamorphic rocks. This tectonic contact, still active during late northward backthrusting and strike-slip faulting, represents the major thrust contact of the ophiolite over the Himalayan sedimentary series.

4. The ophiolite is a thin folded sheet thrust to the south. No data exclude that the ophiolite sheet extend to the north underneath the Xigaze Group flysch as previously suggested by NICOLAS et al. (1981) and BURG (1983). After the southward obduction of the ophiolite, the main tectonic events observed in the ophiolitic series are marked by the folding of the ophiolite sheet and subsequent northward backthrustings of all the structures accompanied by large dextral strike-slip faulting which induced shortening or thickening of the ophiolitic sequence. These late tectonics are ascribed to the India–Eurasia collision. The differences in its intensity, all along the studied area, can be easily explained by differences in the geometry of the India and Eurasia plate boundaries.

5. Late alkaline to calc-alkaline intrusives postdate the main deformations observed in the Xigaze Group as well as in the ophiolite as in the Trias–Lias flysch or Paleocene to Cretaceous wildflysch series.

The *main tectonic events* defined are:

1. Southward primary and probably intraoceanic thrusting of the ophiolite along a N 085°, 50°NW thrust zone producing the low to moderate temperature–large stress

deformations of the peridotites and inducing the formation of the garnet-bearing amphibolites which now form blocks within the ophiolite tectonic breccia.

2. Later southward thrusting of the ophiolite producing the deformation and metamorphism of the Upper Jurassic–Lower Cretaceous red radiolarites and associated sediments and the deformation of the Himalayan series (P1 phases of BURG 1983).

3. General northward backthrusting of all the structures inducing the folding of the ophiolite sheet and associated sedimentary series. This event is followed by large E–W dextral strike-slip motions. These tectonic events correspond to the P2, P3 and P4 phases of BURG (1983).

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