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Structure of Southern Tibet: report on a traverse from Lhasa to Khatmandu organised by Academia Sinica

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A SYMPOSIUM on the Qinghai Xizang (Tibet) plateau was organised by Academia Sinica in Beijing (Peking) in May 1980 and was followed by a field excursion from Lhasa to the China–Nepal border near Khatmandu. Considering the remoteness, high altitudes and formidable logistic problems, the organisation of this field excursion was a very remarkable feat. One was left with feelings of amazement, excitement and gratitude. The Proceedings of the Symposium, at which a vast amount of valuable new data was presented, will be published by Academia Sinica. Because the field excursion traversed a region, for long inaccessible, which contains the type continent–continent collision orogen and includes the famous Indus–Zangbo suture, it seems worth while to describe and discuss the structures seen on the traverse even though many of them were only glimpsed through a bus window. The geological framework for the structural observations is taken from the excursion guidebook (Jixiang *et al.* 1980).

It is generally accepted that the Tibetan plateau owes its unique elevation to a continent–continent collision. However, the mechanism whereby the crust was thickened and how the relative motion of the Indian and Asian plates after collision was accommodated remains uncertain. The northward motion of the Indian plate slowed rapidly from 10^{-1} cm/yr to 5^{-1} cm/yr about 40 Ma ago (Molnar *et al.* 1977). Collision between the continental parts of the Indian and Asian plates is thought, from evidence of this slowing down of the northward motion of India and the influx of north-derived sediment onto the northern edge of the Indian plate, to have occurred in the Eocene (Dewey & Bird 1970, Powell & Conaghan 1973). Since then the Indian plate has moved about 2000 km farther northwards relative to Asia. The collision resulted in thickening of the crust, to about 68 km, south of the Zangbo suture and to between 70 and 74 km north of it (Teng Ji-wen 1980). Whether this thickening is the result of a doubling of the crust by the under-thrusting of continental India beneath Asia or whether it occurred by shortening deformation, or some other process, remains to be demonstrated. Northward underthrusting and deformation, south of the Indus suture, within the Indian plate, is thought to account for less than 500 km of the estimated 2000 km relative motion since collision. It has therefore been proposed (Molnar & Tapponnier 1975) that the rest has been taken up by deformation throughout central Asia, largely by lateral expulsion of crustal wedges bounded by strike-slip faults. The field excursion gave an opportunity to see field evidence relevant to these problems.

The region traversed can be divided (Gansser 1964, Jixiang *et al.* 1980) into the following tectonic units, from north to south (Fig. 1) they are:

(1) Kangdese tectonic unit (Trans-Himalaya)
  (a) Kangdese magmatic belt
  (b) Cretaceous flysch zone (Xigaze Group)
(2) Yarlung Zangbo ophiolite belt (Indus–Zangbo suture)
(3) Himalaya Tectonic Unit
  (a) Mélange zone
  (b) Tethys–Himalayan zone
  (c) High Himalayan zone
  Main Central Thrust (M.C.T.)
(4) Lesser Himalaya Tectonic Unit
  Main Boundary Thrust (M.B.T.)
(5) Sub-Himalaya (Siwalik Molasse Trough)

[(4)–(5): not traversed on field trip]

Central and Northern Tibet, north of the area traversed, consist of older tectonic units but not until the Variscan Kun Lun range 600 km north of the Zangbo suture, are the structures clearly part of the Asian plate that lay to the north of the Tethyan ocean. The Indian plate, with a sedimentary cover of Gondwana facies, is known to extend as far north as the Indus–Zangbo suture (Gansser 1964) and probably farther north (Wang Yujing & Mu Xinan 1980), but the boundaries and evolution of plates or microplates between the Indus–Zangbo suture and the Kun Lun are uncertain.

THE KANGDESE TECTONIC UNIT (TRANS-HIMALAYA)

The Kangdese magmatic belt

The sections studied north and south of Lhasa (Fig. 2a) extend to about 100 km north of the Zangbo suture. The oldest rocks are exposed in a NE–SW trending horst, the Nyainquentanglha Shan. Those seen appeared to be tectonized granites. They are mapped as Precambrian but have not been radiometrically dated. They could be seen, far along the Nyainquentanghla range, to be striking regularly, between N–S and NW–SE, with moderate dips

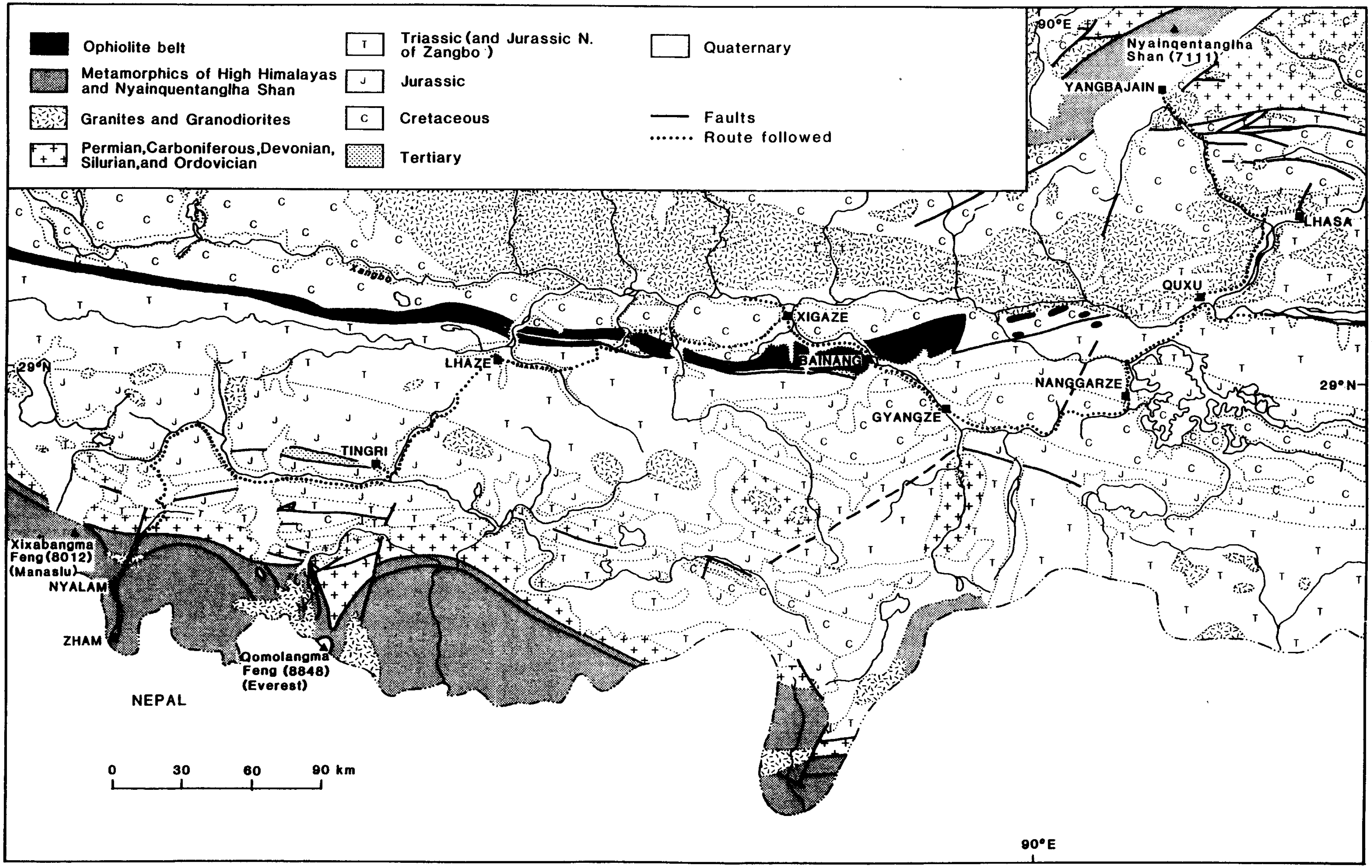

Fig. 1. Simplified geological map of Southern Tibet based on Jixiang *et al.* (1980) to show route of excursion.

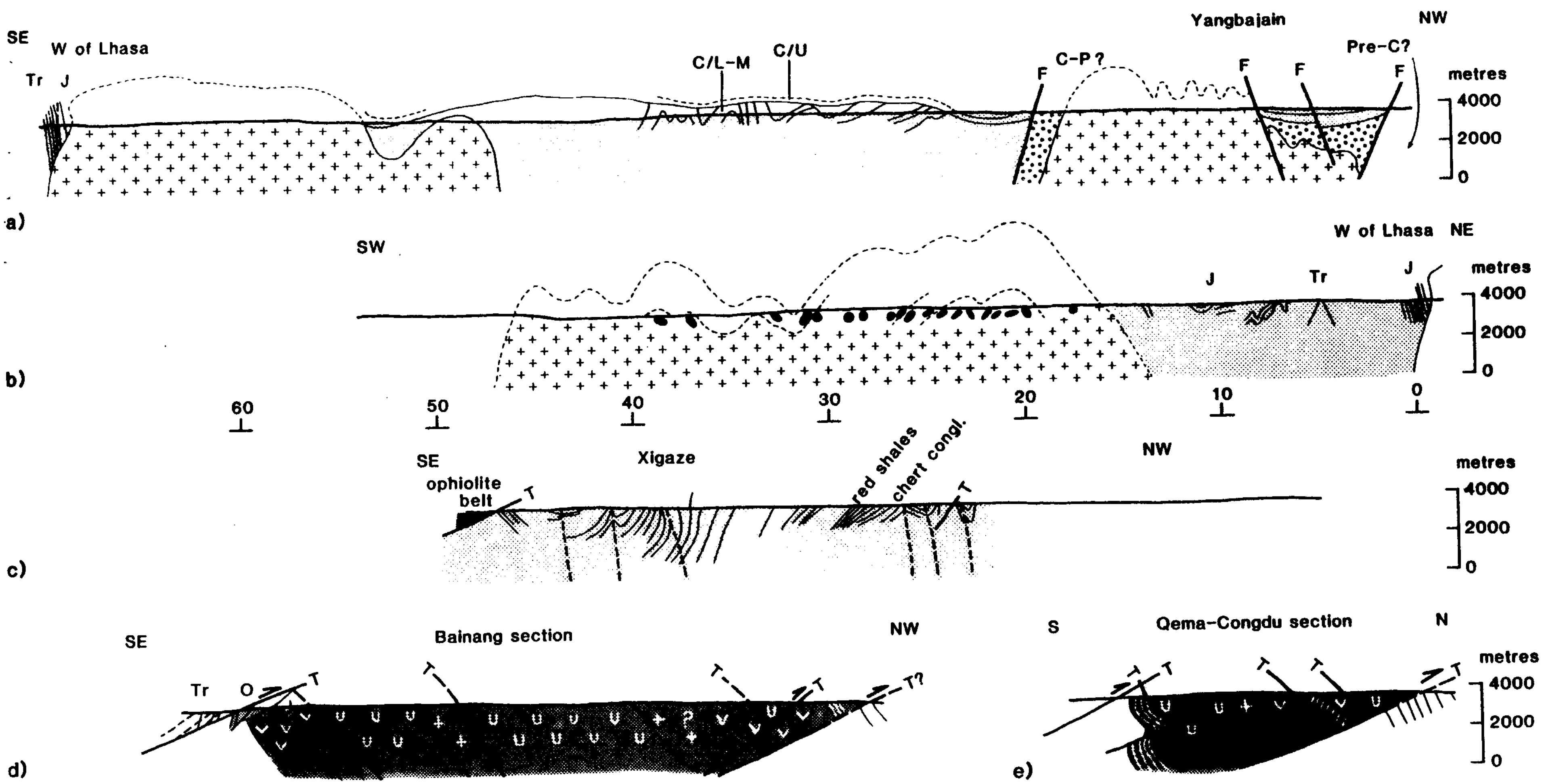

Fig. 2. (a) Section northwest from Lhasa. C/U, Upper Cretaceous, C/L-M, Lower & Middle Cretaceous, J, Jurassic, Tr, Triassic, C-P, Permian-Carboniferous?, Pre-C, Precambrian, crosses, plutonic rocks. (b) Section southwest from Lhasa. J, Jurassic, Tr, Triassic, Di, diorite, crosses, granodiorite and granite, black ellipses, deformed xenoliths. (c) Section through Xigaze. (d) Bainang section southeast of Xigaze. O, Oligocene conglomerates, Tr, Trias?, ≡, radiolarites, V, pillow lavas, llll, sheeted dykes, +, gabbro, U, ultramafic. (e) Qaina–Congdu section, south-southeast of Xigaze. Symbols as in Fig. 2(d). Horizontal and vertical scales are equal in all sections.

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northeastwards; adjacent slates, quartz schists and marbles, mapped as Carboniferous—Permian?, also locally strike NW–SE and dip NE (Jixiang *et al.* 1980, fig. 11-1). These strikes, strongly oblique to the E–W Himalayan structures, suggest pre-Mesozoic deformation. Whether this is Precambrian or Variscan seems uncertain; but the presence of such rocks must imply pre-Mesozoic continental crust here. If Variscan, the Kangdese tectonic unit was probably part of the Asian plate before the Mesozoic, but if Precambrian, the unit might have been an island arc related to the Indian plate. The palaeomagnetic evidence, discussed at the Peking symposium, is inconclusive in deciding when the Kangdese unit became part of the Asian plate. Palaeontological evidence (Wang Yujing & Mu Xinan 1980) indicates a Gondwana facies for the Permian and Carboniferous rocks in this unit, supporting the view that it was an island arc related to the Indian plate, the suture between the Indian and Asian plates being still farther north (at about 32° N). Cretaceous, Jurassic and Triassic sediments, Cretaceous calcalkaline volcanics and Cretaceous and Tertiary plutonic rocks underlie the country south of the Nyainquentanglha Shan. There is a major unconformity between the gently undulating Upper Cretaceous Linzizang Formation, mainly andesitic, dacitic and rhyolitic volcanics, and strongly folded earlier Cretaceous and older sediments. Extensive calcalkaline plutons (diorites, grandiorites and granites) invade these Mesozoic rocks. Some of the plutons intrude the Upper Cretaceous but most appear to be older, being unconformably overlain by the Upper Cretaceous. This plutonic zone extends semi-continuously, north of the Zangbo–Indus suture, for at least 2500 km (Gansser 1980, pl. I). Most of the calcalkaline extrusive rocks are Upper Cretaceous but some calcalkaline volcanics were seen within the folded pre-Upper Cretaceous succession. The extensive calcalkaline Cretaceous and early Tertiary magmatism indicates subduction and an underlying Benioff zone during the Cretaceous and early Tertiary.

The folds in the Triassic, Jurassic and pre-Upper Cretaceous rocks are upright, with a weak, nearly vertical, axial plane cleavage at structurally deeper levels. Shortening, mainly by buckling folds, but partly by cleavage flattening, is perhaps 20 or 30%. Part of this deformation may be attributable to the introduction of very large volumes of magma from below the crust. Xenoliths are strongly flattened near the margins of the plutons whether the contacts dip steeply or gently and the XY plane is parallel to the contacts, not to the cleavage in the country rocks, indicating distension during diapirism (Ramsay personal communication) rather than post-intrusion tectonic deformation. The general, nearly vertical dip of the cleavage suggests that it is due more to tectonic shortening than to the plutonism.

The Cretaceous flysch zone

Between the plutons of the Kangdese zone and the Zangbo ophiolite belt is a synclinorium of sediments, the Zigaze Group (Fig. 2b). These sediments are mapped (1 : 1.5 million geological map in Jixiang *et al.* 1980) as Upper Cretaceous but their structures are similar to those in the pre-Upper Cretaceous rocks north of the plutons and unlike those in the very weakly deformed Upper Cretaceous succession. Fossils found by participants of the excursion (Kauffmann, personal communication) also suggest a pre-early Cretaceous age. The rocks display open to tight folds, box-folds and chevron folds, with a weak steeply-dipping axial-plane cleavage. At one locality about 6 km south of Xigaze, earlier north-facing recumbent folds were seen, crossed by the regional steep cleavage. These early folds may be due to large-scale northward slumping.

The major structure of the zone is a synclinorium, with an E–W axial trace about 4 km south of Xigaze. The southern limb is partly cut out by northward-directed thrusts at and near the contact with the ophiolite belt. Similar thrusts occur near the Zangbo River northwest of Xigaze. The base of the Xigaze Group was not seen. The lowest rocks studied were a remarkable series of conglomerates and grits intercalated in red mudstones and siltstones. The coarse units are sharply defined, up to 5 m thick, almost unstratified, crudely but distinctly graded and display flute casts at their bases. Giant flutes below the thickest conglomeratic unit are nearly 1 m deep. Transport directions were from the SE (135°, 165°, 125° in different units). The pebbles are mostly of red, green and grey chert, presumably radiolarite, with others of limestone, vein quartz, dolerite, andesitic tuff (?) greywackes, and orthoquartzite. These rocks, especially the cherts, resemble those on the south side of the Zangbo ophiolite belt; no such rocks are known to the north. Much higher in the Xigaze Group, on the crags overlooking Xigaze, totally different boulder conglomerates, also in thick (up to 4 m) graded units, are associated with graded greywackes and are interbedded with greenish siltstones. The pebbles and boulders are of andesite, granodiorite, quartz-porphyry, tuff and other calcalkaline plutonic and volcanic rocks, with a few of limestone and quartz and ripped-up shaly slabs. This assemblage was clearly derived from the Kangdese magmatic belt to the north.

The Xigaze synclinorium appears to represent a trench, which was rapidly filled, at first from an oceanic slope to the south, and finally with coarse detritus from the volcanic arc or Andean chain to the north. It occupies a position analogous to the (Eocene) Indus Flysch north of the Indus suture in the western Himalayas (Gansser 1964).

THE YARLUNG ZANGBO OPHIOLITE BELT

Two sections (Figs. 2c and d) less than 30 km apart, to the south and southeast of Xigaze, were studied. The belt, trending E–W, is here about 15 km wide. A complete though dismembered ophiolite sequence is recognizable: tectonized harzburgites are the main rocks present, together with layered gabbros, sheeted dykes and variolitic pillow lavas. The ophiolite complex is associated with radiolarites. In the sections visited, dips are predominantly northwards, and in the few places where facing directions could be determined, as for example in pillow lavas and distal turbidites associated with radiolarites, it was northwards. The least disrupted parts of the ophiolite sequence also appeared to face north. The few unequivocal sheeted dykes which were measured trend E–W and dip 50–70° S, that is roughly normal to the general northward dip. In the few places where it was measured, a foliation in the tectonised harzburgites, shown by the shape and alignment of bastite pseudomorphs, strikes NNE-SSW with variable dips to the east or west of between 40 and 90°. These unexpected orientations deserve further study.

The structure of the ophiolite belt indicates a sequence of superimposed deformations. The latest of these produced a series of northward overthrusts, affecting not only the ophiolites but also a red subaerial conglomerate (the Liuqu Conglomerate) of Oligocene to Miocene age, which unconformably overlies the ophiolites. The northward directed thrusts, probably Miocene in age, form both margins of the ophiolite belt in the area traversed. They can be compared with the northward overturning (*retrocharriage*) of the Indus ophiolite belt in Ladakh (Gansser 1964). Northward overfolding is conspicuous in the lower part of the ophiolite section studied (Fig. 2d) and is also seen to affect the Liuqu Conglomerate. Older than these Miocene thrusts are much more extensive pre-Oligocene north-dipping thrusts, interpreted as northward underthrusts. The effect of these structures is to repeat the ophiolite as huge slabs, and in the lower part as lenses and slices. The north-dipping thrusts are subparallel to the layering. No regular imbrication was recognized, and no associated folds.

The oldest structure observed is the foliation, probably an upper mantle structure, in the tectonized harzburgites. Along the southern side of the ophiolite belt, southeast of Xigaze, the dislocations are so closely spaced and anastomosing that the result is an ophiolitic mélange. This mélange is treated here as part of the ophiolitic belt because the components seen are all of ophiolites or sediments associated with them, there appears to be no matrix between the slices, and the dislocations separating them are indistinguishable from those separating larger and more continuous slices of ophiolite at a higher structural level. The mélange is thus interpreted as a tectonic mélange. One large tectonically bounded slab consists of purplish highly vesicular basalt, rubbly at the top, overlain by red silts (3 m) with turbidite laminae, rubbly basaltic conglomerate (2 m), grey cherts (30 m) and thin black shales with sandstone and limestone bands. This lens may represent part of a seamount and its cover.

Extending along the southern side of the ophiolite zone for several hundred kilometres is a package of Cretaceous and possibly Jurassic radiolarite slices. Small thrust slices of similar radiolarite occur within the ophiolites but none were seen at the top, where the pillow lavas are overlain locally by umber, ferromanganoan sediments and then by pelagic sediments. The basal radiolarite slices, tectonically separated from the overlying harzburgites, probably represent material scraped off a descending oceanic slab.

There is some doubt whether the Zangbo–Indus ophiolite belt dips northwards under the Asian plate or southwards under the Indian plate. In the western Himalayas the Indus ophiolite belt commonly dips steeply southwards (Gansser 1964), while along the Zangpo, the ophiolites structurally overlie the rocks to the north. The sections visited show that the ophiolites are thrust northwards over the Cretaceous flysch zone but that these thrusts only cut out a few kilometres of the southern limb of the Xigaze flysch synclinorium. The evidence that the Indian plate dips under the plate to the north of the Zangbo suture may be summarised as follows.

(1) The northward facing in the ophiolites.
(2) The northward dip in the ophiolites.
(3) The presence of ophiolite mélange, underlain by sedimentary mélange, on the south side of the ophiolite belt. Such mélanges, in this order, underlie ophiolites at many places in the Tethyan zone (Glennie *et al.* 1974, Stocklin 1977, Ahmad & Abbas 1979).
(4) The persistent dip north of cleavage and axial planes and the south facing directions of structures, across the whole Himalayan zone (see Figs. 2–4).
(5) The occurrence of klippen of ophiolites far to the south of the suture in the western Himalaya (Gansser 1964).
(6) The constant presence of calcalkaline plutons parallel to, and north of, the belt, indicating a Benioff zone dipping under the plutons.
(7) The moderate horizontal shortening in the Kangdese zone, comparable to that in the Andes above a Benioff zone, but unlike the far more intense deformation characteristically found below Benioff zones.

THE HIMALAYAN TECTONIC UNIT

The sedimentary mélange

Immediately to the south of the Zangbo ophiolite belt, there is a vast sedimentary mélange. This extends discontinuously for at least several hundreds of kilometres along strike and for at least 10 kilometres across strike. The contact between this sedimentary mélange and the ophiolitic mélange or ophiolites is abrupt and the components of the two are quite different, suggesting that the contact is tectonic. The southern contact of the sedimentary mélange with the sediments to the south is also (where visited) abrupt and thus probably tectonic.

The most distinctive feature of this sedimentary mélange is the occurrence of huge exotic blocks up to 2 km long of Permian crinoidal limestones, with slabs and sheets of Triassic sandstones shales and limestones, blocks of radiolarite (Cretaceous) and limestones with Cretaceous microfossils. The mélange is clearly, though crudely, layered, and dips gently northwards in most places. Contacts between the blocks, which where competent are angular rather than lenticular, are commonly discordant to bedding, and the bedding dip varies from block to block. In parts of the fine-grained pelites (Triassic) there is a distinct phyllitic schistosity subparallel to the general layering or bedding.

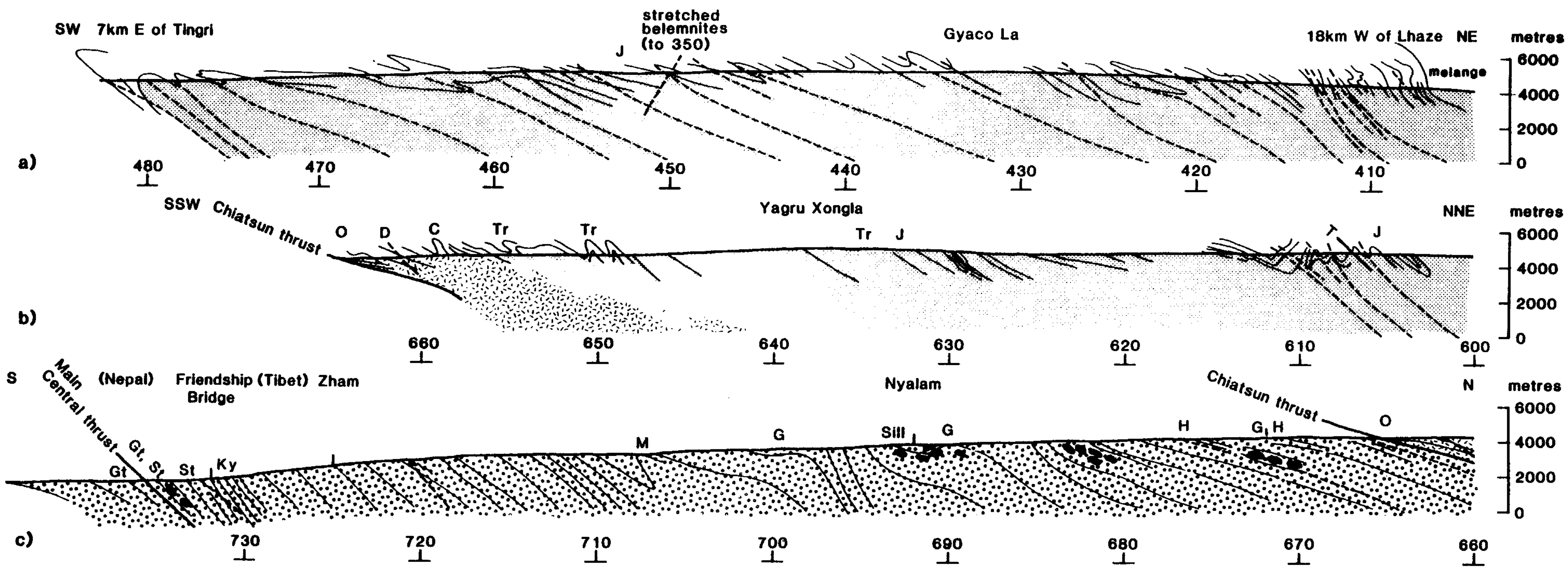

Fig. 3. (a) Section from west of Lhaze to east of Tingri. (b) Section from Chiatsun. O, Ordovician, D, Devonian, Tr, Triassic, J, Jurassic. (c) Section from Chiatsun to Friendship Bridge. O, Ordovician, black ellipses, augen gneiss, M.C.T., Main Central Thrust, Gt, garnet, St, staurolite, Ky, kyanite, Sill, sillimanite, M, migmatite, G, granite, H, hornfels. In all three sections the following ornament is used: stipple, Mesozoic, oblique dashes, Palaeozoic, open circles, metamorphic rocks, heavy pecked lines, cleavage. Numerals below sections are kilometre posts. Horizontal and vertical scales are equal in all sections.

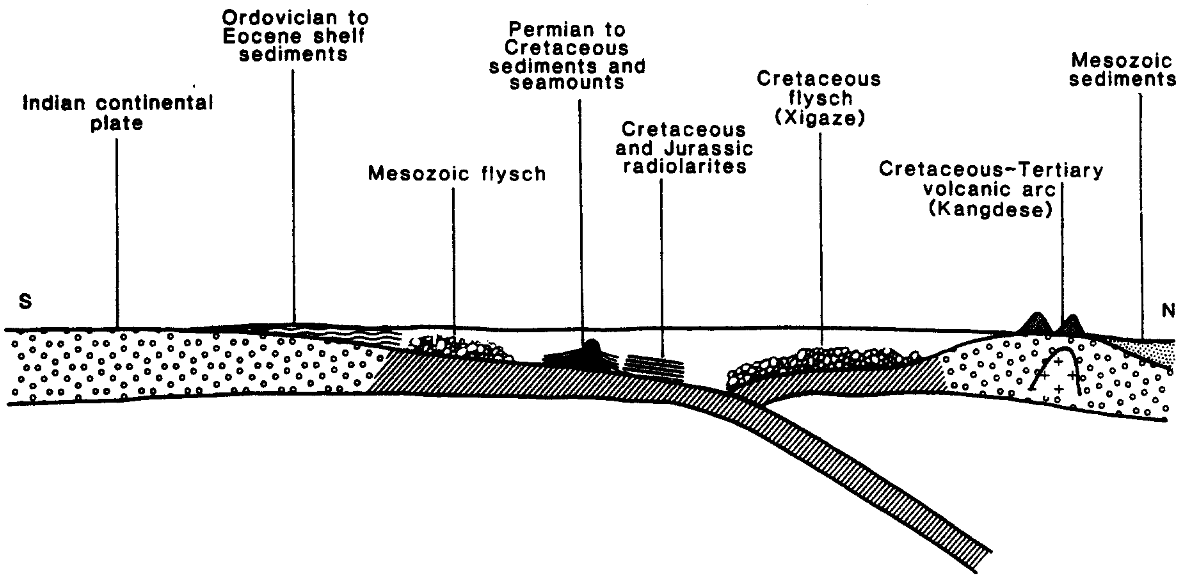

Fig. 4. Diagram to show supposed distribution of different facies before subduction and collision.

The sedimentary mélange is similar in field aspect to the Monian mélange in Anglesey (Greenly 1919, Shackleton 1969), to the *argille scagliose* in the Apennines (Abbate *et al.* 1970) and to the mélange beneath the Semail nappe in Oman (Glennie *et al.* 1974), all of which are interpreted as olistostromes. On the other hand, the stacking order, with radiolarite slices above pelagic sediments with possible seamount complexes in the sedimentary mélange, which in turn are underlain by turbidites, is the opposite to that which would be anticipated as a result of a sequence of slides into a trench. Moreover the age and facies contrasts imply juxtaposition of sediments which were originally far apart (Fig. 4). Therefore the possibility that the sedimentary mélange represents materials scraped off a descending slab, or tectonized olistostromes, cannot be excluded. A mélange (Zonghuo Formation) seen about 40 km south of the ophiolite belt between Nanggarze and Gyangze (see Fig. 1) contains angular blocks of radiolarian chert in a pelitic matrix of Cretaceous age. It is reported also to contain fragments of basic lava, sandstone, conglomerate and ultramafic rocks. It is underlain by sandy Lower Cretaceous sediments and is clearly an olistrostrome. Were it to be shown that it can be correlated with the sedimentary mélange immediately south of the ophiolite, this would imply that both are olistostromes and that the thinner Zonghuo mélange, with its smaller clasts, represents a more distal facies, implying a southward direction of tectonic transport.

Tethys Himalayan belt

This belt (Fig. 3a) is nearly 100 km wide. It contains a fossiliferous marine sedimentary sequence, essentially continuous from Ordovician to Eocene, representing shelf conditions to the south, deeper water to the north (Jixiang *et al.* 1980). A slaty cleavage, axial planar to tight folds, persists across the whole section, dipping consistently northwards at low to moderate angles (10–40°). Stretching, in a NNW–SSE direction, is general and is taken to represent the movement direction. Hinges of tight to isoclinal folds, facing south, are frequently to be seen and innumerable others are implied by abundant reversals of bedding/cleavage relations, but because right-way up limbs appear much more extensive than inverted ones, it must be assumed, to avoid postulating an impossible thickness, that there is also much repetition by thrusts, some of which have been mapped.

The age of the cleavage and the tight to isoclinal folding is not clear. Cleaved, even phyllitic, sediments on the northern side of the Himalayan unit are thrust over uncleaved Oligocene (Liuqu) conglomerates and the cleavage here is clearly pre-Oligocene. Farther south near Tingri the deformation involves Eocene limestones which apparently follow the Cretaceous without any break. Thus the cleavage in the Tethys Himalayan zone appears to be late Eocene; the intensity of the cleavage and the grade of metamorphism seem to diminish southwards across the belt.

The High Himalayan belt

The High Himalayan belt (Fig. 3b) is separated, at the traverse line, from the Tethys Himalayan belt to the north by the northward-dipping Chiatsun thrust. Above this thrust are fossiliferous Ordovician limestones, right-way up, with a weak cleavage dipping a little more steeply northward than bedding. Below the thrust there are pelitic sediments penetrated and hornfelsed by many concordant foliated granite sheets and crosscutting tourmaline granite and aplite dykes, some foliated parallel to their crosscutting margins. The Chiatsun thrust is described as a zone of cataclastic granitic gneiss up to hundreds of metres thick, associated with structures indicating relative movement of the hanging wall towards the south (Jixiang *et al.* 1980).

Southwards and structurally downwards, the metamorphic grade rises, giving sillimanite–muscovite migmatites about 15 km south of Chiatsun. Within the high-grade rocks is a sheet of tourmaline granite several kilometres thick, which represents the Himalayan granites, elsewhere giving Oligocene (28 Ma) dates (Hamet & Allegre 1976). There are also numerous bodies of augen gneiss, which may, like those in Nepal (Pecher & Le Fort 1977) be of Early Palaeozoic age, though deformed during the Himalayan event. Sillimanite–muscovite migmatites, metasediments and augen gneisses continue to Zham, near the Nepal border, where the metamorphic grade declines, again structurally downwards, as shown by successive assemblages with kyanite and sillimanite, kyanite, staurolite, staurolite and garnet, garnet, and biotite. This is the famous inverted metamorphic sequence known all along the southern side of the High Himalayas.

The schistosity, folding, stretching lineation and thrusting throughout the High Himalayan zone appear to be similar to corresponding structures north of the Chiatsun thrust. Flattening in the plane of the foliation is more intense and features on the mountain sides suggest the presence of abundant closely spaced parallel thrusts. Fold hinges are difficult to see on the densely forested precipices which have been eroded in the high-grade rocks and the polyphase deformation is complex, but variable relations between schistosity and layering clearly show that tight to isoclinal folds with a northward-dipping axial-planar schistosity prevail throughout the zone. The concept of a Precambrian Tibetan slab (*Dalle du Tibet*) underlying the Tethys Palaeozoic sequence (Lombard 1958, Gansser 1964) is untenable. The structures and metamorphism now seen in the rocks are Tertiary, whatever the age of the sediments themselves.

The Main Central Thrust (M.C.T.) taken as the limit between the High and Lesser Himalayas is mapped about 2 km south of the Nepal/China border, within garnet mica schists some 200 m below the lowest horizon of augen gneiss. There is no metamorphic break, but a steep metamorphic gradient. The M.C.T. must be at least largely pre-metamorphic and a shear zone rather than a single thrust, as recognised elsewhere. The zone of high-grade metamorphic rocks thus occupies a tight or isoclinal thermal anticline, the lower limb of which is replaced by the M.C.T. No clear evidence was seen to prove whether the inverted metamorphic sequence coincides with an inversion of the stratigraphic sequence. Relations between layering and early schistosity (there are several schistosities and crenulations) indicate at least some inversion here, for example in staurolite schists 300 m south of the border, but the folding is so tight that much more detailed work would be needed to show whether a major stratigraphic inversion exists. Elsewhere in the Himalayas, the metamorphic inversion is associated both with inverted and right-way up successions.

CONCLUSIONS

(1) The voluminous calcalkaline magmatism in the Kangdese tectonic unit, north of the Zangbo suture, implies the presence of an underlying Benioff zone, where back-arc or oceanic crust was being subducted northwards through Jurassic and Cretaceous times (Fig. 5). It is not clear whether the Kangdese zone was then an Andean range on the southern side of the Asian plate, or was an island arc, that is part of a microplate within Tethys. The structures, showing weak (20–30%) Cretaceous shortening, part of which may be attributable to the introduction of large volumes of magma, are consistent with either an Andean or island arc model.

(2) The Zangbo ophiolite belt consists of north-facing, north-dipping slabs and lenses of ophiolite components. The lower part, consisting of smaller, more varied and more chaotically arranged lenses, is a tectonic mélange. The lowest unit consists of tectonically repeated radiolarite slices. Deformation increases downwards through the ophiolite belt. The northward-dipping ophiolite complex was elevated above sea level and eroded by Oligocene times, and thrust northwards a few kilometres in the Miocene.

(3) The Zangbo ophiolite belt is underlain by a sedimentary mélange containing exotic blocks ranging in age from Permian to Cretaceous. It has the appearance of an olistostrome but may have been scraped off the descend-

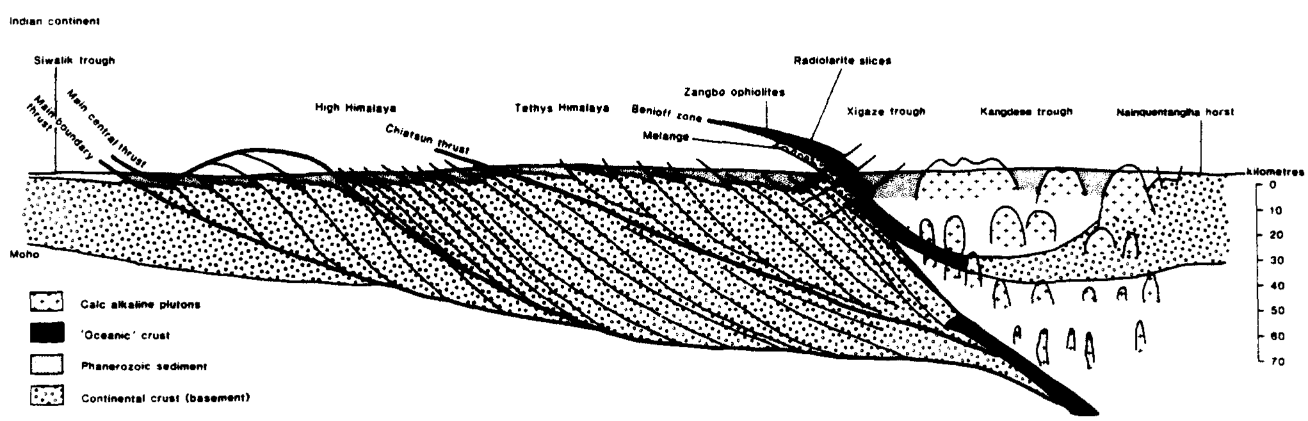

Fig. 5. Diagrammatic section to show interpretation of crustal structure. Horizontal and vertical scales are equal.

ing slab. It was thrust northwards over the ophiolite belt in the Miocene, but the persistent gentle dip north of layering and cleavage, in this as in all of the Himalayan zones, shows that the mélange originally dipped northwards under the ophiolite belt; from which it was separated by the main subduction surface or Benioff zone.

(4) Deformation, expressed by a cleavage dipping northwards, by tight southward-facing folds, southward directed thrusts, and NNW stretching, affects the whole Himalayan zone. There is a zone of strong deformation, mainly shown by intense thrusting and disruption, at the southern side of the ophiolite belt. From here southwards, the intensity of the deformation appears to decrease through the Tethys Himalayan unit. It then increases again dramatically, to a maximum in the High Himalayan zone, where it is associated with the effects of crustal melting and high-grade metamorphism.

(5) The inverted metamorphic sequence at the southern side of the High Himalayas is superimposed on the shear zone known as the Main Central Thrust (M.C.T.). The shear zone represents the sheared-out inverted limb of an anticlinal, hot nappe core.

(6) The locus of maximum deformation migrated southwards from the Kangdese zone (Cretaceous) to the Zangbo ophiolite belt and south of it (Eocene), the High Himalayas and M.C.T. (Oligocene) and Main Boundary Thrust (Miocene onwards). The deformations south of the Zangbo represent a series of north-dipping crustal shear zones resulting from collision (Fig. 5).

(7) The observed deformations can account for the thickening of the continental crust south of the Zangbo suture. The even greater thickening of the crust north of the Zangbo suture is more plausibly attributed to Andean-type underplating. The facies of the sediments being subducted under the Zangbo ophiolites indicate deposition on oceanic crust, perhaps suggesting that the Indian continental crust was not pushed under Central Tibet.

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