Chapter 5
Structure

The district forms but a small section of the tectonic zone of southeast China, where Palaeozoic and other rocks form a basement which is overlain and flanked to the south and east by Mesozoic rocks. The younger rocks are largely volcanic and plutonic intrusions assigned to the Yenshanian orogeny, spanning the Jurassic/Cretaceous boundary (Bennett, 1984c). Later thrusting was postulated by Ruxton (1960) in the mid-Tertiary, during which time dyke intrusion was also active.

The Yuen Long district lies across the Tuen Mun-Lo Wu Fault Zone, which is dominated by northeast trending dislocations with both normal and reversed throws (Figure 6). The fault pattern is complex, with numerous sub-parallel shear zones containing brecciated and mylonitised rocks showing evidence of transcurrent movements (Figures 7a & b). These dominant elongate and curving faults are displaced by a minor set of later structures trending roughly northwestwards. Both sets of dislocations are intruded by dykes, and quartz and calcite filled veins. Folding is also present but masked by the intense faulting and metamorphism of the region. Allen & Stephens (1971) considered that the Lok Ma Chau Formation was inverted, and interpreted the structure as a series of recumbent isoclinal folds. Recrystallisation of the carbonate rocks towards the top of the Yuen Long Formation has destroyed most traces of bedding. The lower part of the sequence shows complex but disrupted bedding which is difficult to interpret solely as having a tectonic origin. Penecontemporaneous earthquake activity and/or mass movement, and submarine slumping and sliding of unconsolidated strata (olistostromes) may explain some of these structures. The upper arenaceous Lok Ma Chau Formation is less disrupted overall, but where adjacent to major granite plutons is altered to phyllite in a zone over 0.5 km wide.

Granite Plutons

The Palaeozoic basin of the district is surrounded by granitic and volcanic rocks. The granites are considered to underlie the basin, and in places intrude and are faulted and thrust against strata within the basin. The northwestern margin of the basin is bordered by the Tsing Shan granite pluton, separated from the Palaeozoic and younger sediments by the Yuen Tau Shan Fault. This boundary was located near Lok Ma Chau in boreholes associated with the new border road crossing. An inclined borehole (BGS 36) was drilled at 20° to the vertical to intercept this fault, and the contact was proved to be very steeply dipping at 70° to 90°, irregularly curved, and displayed near vertical slickensiding. The granite was mylonitic for a width of 3 m adjacent to the fault, and a 2 m thick fault zone comprising a green silty matrix containing granite and quartz fragments separated the granite from the grey-green phyllite making up the country rock. Mineralisation in the form of calcite and quartz is common, with purple and green fluorite also present. Although this boundary fault to the Palaeozoic basin is near vertical near the surface, it may increase in hade at greater depths, as the adjacent minor structures show considerable evidence of movement and shear. The adjoining zone of phyllites comprises pale grey sporadically laminated siltstones interbedded with finely laminated green silty clays. These softer horizons commonly act as shear planes, with truncation of laminae at both top and bottom. Small-scale faults are well displayed in the more cohesive strata and, in places, complete disruption of the siltstone laminae occurs, resulting in their random orientation within the softer clays.

To the southwest of Yuen Long, ground investigation boreholes adjacent to the Lau Fau Shan road [186 341] showed granite forming the southern margin of the basin. Here a cupola of granite rises to within a few metres of Principal Datum, forming part of the rockhead beneath the superficial deposits of the area. The intrusion falls away on all sides (Figure 8) at angles of about 45°. In places marble forms the roof of the intrusion and the thermal alteration of the marble has produced considerable veining and fracturing. Scaly partings in the marble suggest the bedding is near vertical. Mineralisation is confined to calcite and quartz.

Volcanic Rocks

Intimately associated with the granite plutons are volcanic rocks of a similar age. These rocks of the Repulse Bay Volcanic Group bound the Carboniferous and younger sediments to the southwest and east of the basin. The eastern margin comprises a curving thrust fault trending northeastwards. It was exposed in a temporary roadside section near Mai Po [242 387]. Here, mylonitic graphite schist and

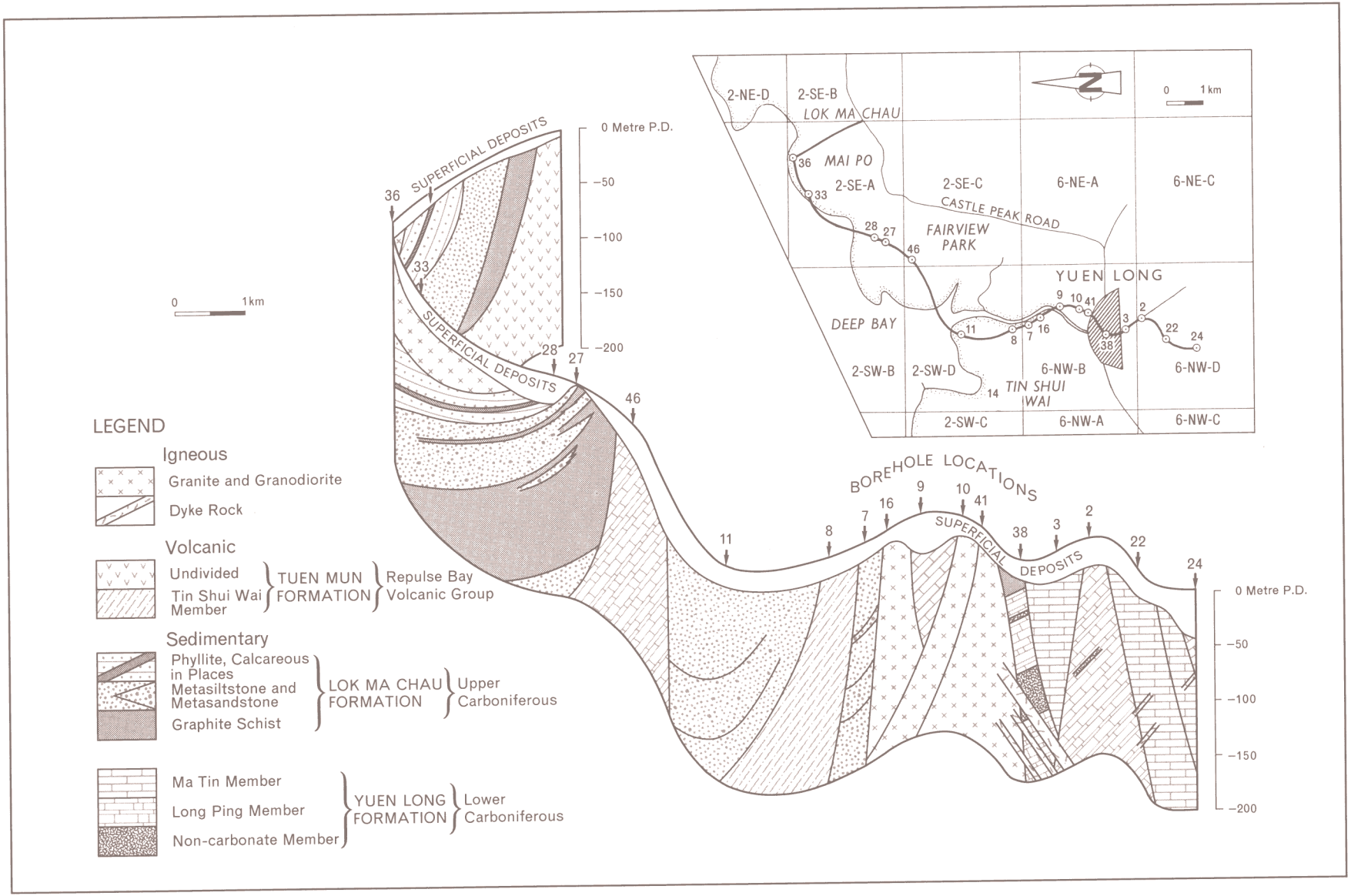

Figure 6 - Ribbon Section Showing the Structural Framework of the Designated Area

Figure 7a - Main Structural Features of the District, Yuen Long

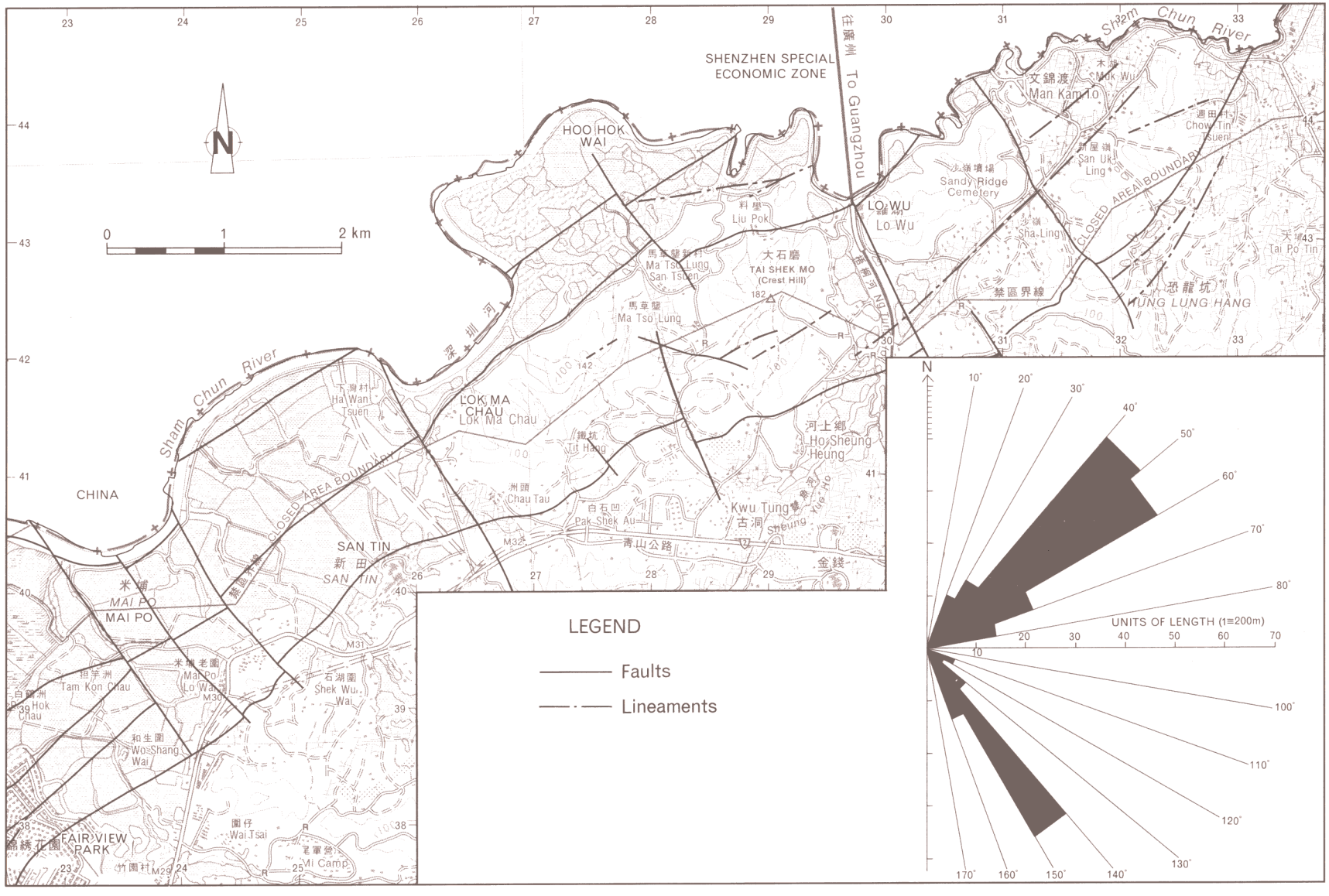

Figure 7b - Main Structural Features of the District, Lok Ma Chau

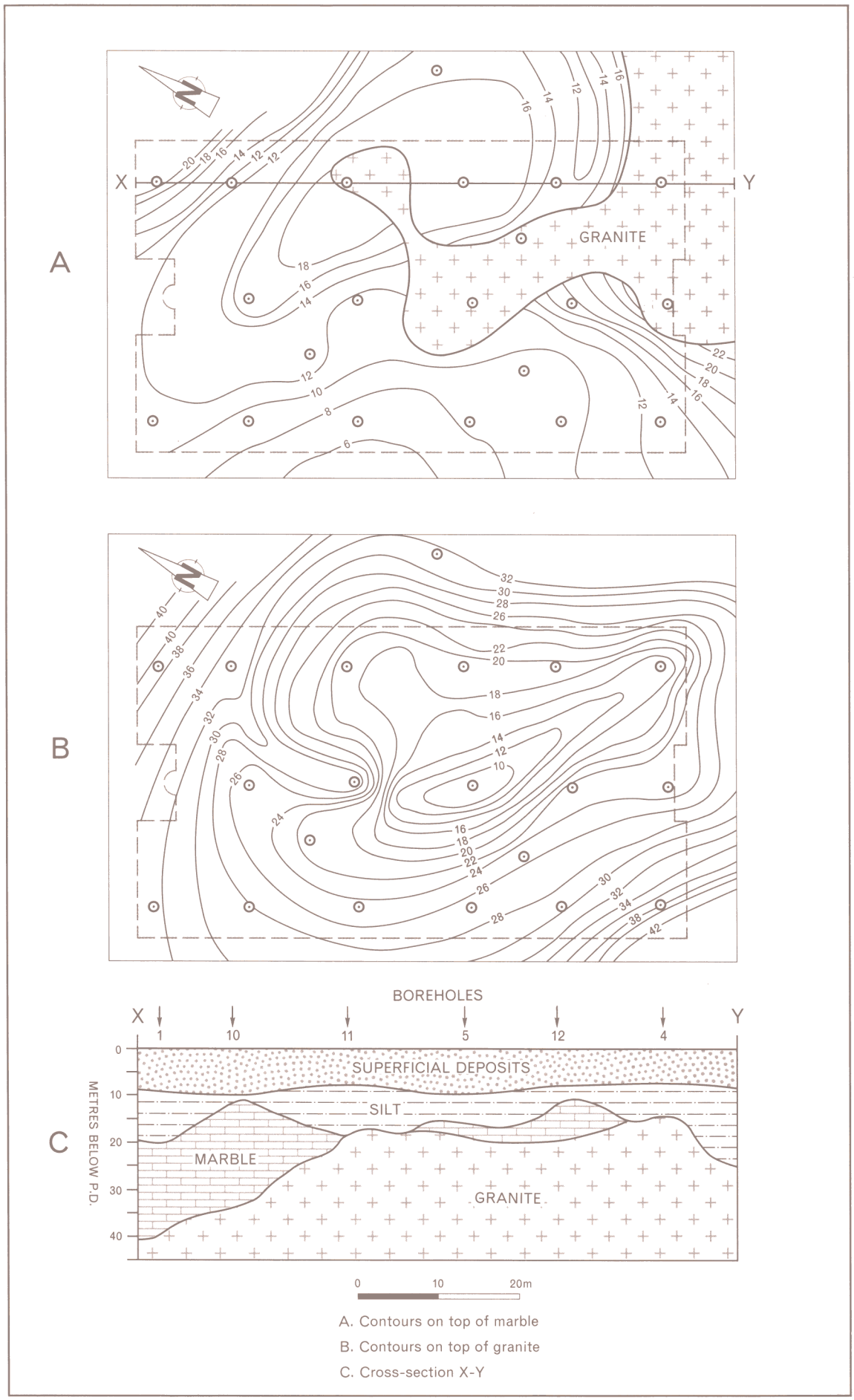

Figure 8 - Marble/Granite Association in a Site Near Tin Shui Wai

metasiltstone of the Mai Po Member were thrust eastward over tuff of the Tai Mo Shan Formation, with the angle of the thrust plane at 65° to 67° to the horizontal (K. W. Lai, oral communication, 1989). Within the same excavations, northwest-trending cross-faults were exposed affecting the Mai Po Member. These normal faults (hade 15°) cause offsetting of the volcanic thrust boundary. Further south, on the eastern margin of Yuen Long, the volcanic/Carboniferous boundary is concealed beneath thick superficial deposits. Boreholes on or near this contact showed completely weathered tuff to a depth of at least -106 mPD. Some 5 m of marble proved from -55 mPD to -60 mPD were interpreted as a fault-slice within the thrust zone.

The southern and western side of the Palaeozoic basin, originally classified as Carboniferous siltstone and marble, has now been interpreted by Darigo (1989) as comprising volcanic breccia containing marble clasts (Tin Shui Wai Member of the Tuen Mun Formation). The breccias, steeply dipping to the northwest, are interbedded with fine ash tuffs and siltstones. The rocks of this member have been metamorphosed, and these effects are greatest in the northern part of the subcrop where the marble clasts have been severely stretched to give an appearance of banded marble. Deep weathering is again an important feature of the margin of the basin, which has been proved to depths of -140 mPD.

Folds

The Carboniferous strata in the district were affected by intense and complex faulting followed by metamorphism which has masked the earlier structures and resulted in a dominant northwesterly dipping foliation. More than one set of movements and more than one stage of metamorphism have further complicated the structural interpretation of the district. The overall pattern of faulting reflects an effective response to an approximate east-west compression of the Carboniferous basin. Langford *et al* (1989) distinguish two periods of folding, with Palaeozoic and Mesozoic folds both aligned northeast to northnortheastwards. Minor curving axes have been mapped near Lo Wu, with a northnortheast and northnorthwest trend. The Palaeozoic anticlines are thrust-faulted along their axial planes.

The main structure of the Yuen Long district is anticlinorial, with older carbonate rocks of the Yuen Long Formation overlain both to the east and west by the younger Lok Ma Chau Formation. This is obviously an oversimplification, but detailed structural interpretation in the carbonates is impossible with the original bedding traces destroyed by metamorphism and recrystallisation. The Long Ping Estate area of Yuen Long is underlain by dark grey marble of the Long Ping Member considered to be the oldest Carboniferous formation (Figure 9). These subcrops may be interpreted as either isolated thrust-blocks or klippen of the Yuen Long Formation, or the eroded core of the Yuen Long carbonate anticline. The latter would require a considerable unconformity between the Yuen Long Formation and the Lok Ma Chau Formation. This is possible as the two formations are probably close correlatives of the Mississippian and Pennsylvanian of North America, or the Dinantian and the Namurian/Westphalian of Europe, which in places are separated by considerable time breaks. The earliest karstification in Yuen Long may have commenced in the late Dinantian (about 325 Ma).

Faults and Joints

The main northeasterly trending faults of the district commonly occur over a broad zone comprising a plexus of parallel or sub-parallel dislocations. Fault planes show evidence of movement by numerous slickensided surfaces. A steeply inclined joint dipping at about 80° in the Ma Tin Road Borehole showed slickensides crossing the joint face at 20° to the horizontal. Transcurrent movements commonly take place along partings which have been lubricated by clay and mica. The larger, longer faults comprise crush-zones of brecciated and mylonitised strata associated with a high degree of local dynamic metamorphism as evidenced by the growth of metamorphic minerals such as garnet.

Figures 10 & 11 summarise the faulting and jointing in the district. The northeasterly trending dextral slip faults were dominant in the Palaeozoic rocks, whilst the complementary set trending northwestwards, although present in the Carboniferous strata, did not become important dislocations until later in Tertiary times; they often showed a sinistral movement. The normal fault planes have hades between 20° and 40°, but the reversed throw, thrust, and transcurrent faults are flatter lying structures which show curvature in both vertical and horizontal planes. Although the original set of joints would have a northerly orientation, the transcurrent movements transform these joints into sigmoidal fractures with areas aligned parallel with the main faulting direction. This feature is confirmed by Houghton (1988) by analysis of joints measured from boreholes in the south of Yuen Long. Tension gashes are usually good indicators of tectonic strain and in this district should, according to the theoretical strain diagram, be aligned east-west. However, the complex tectonic and metamorphic history has resulted in a melange of calcite- and quartz-filled gashes incapable of resolution with the present information.

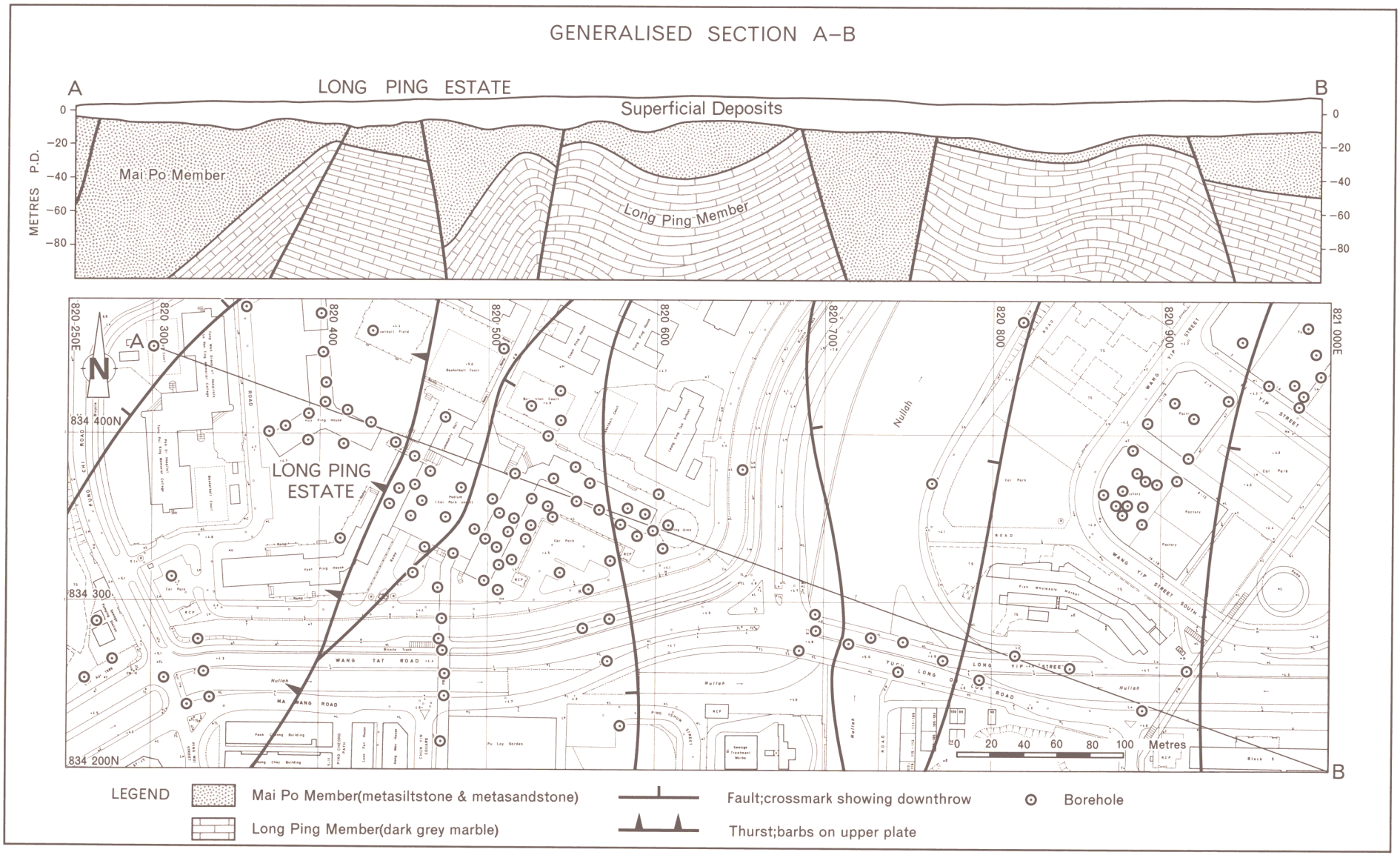

Figure 9 - Structure of the Long Ping Estate, Yuen Long

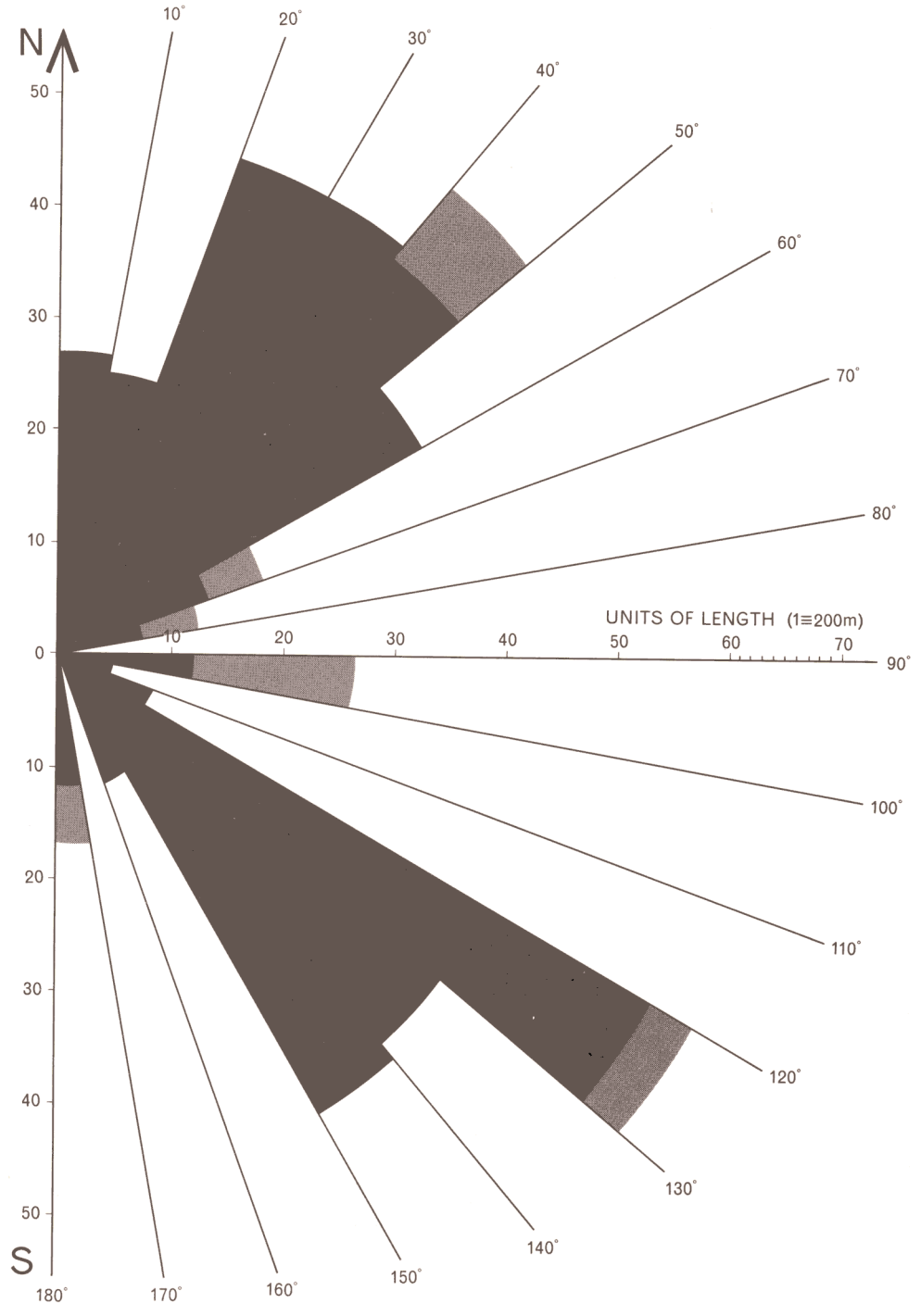

Figure 10 - Rose Diagram of Faults of the Yuen Long District

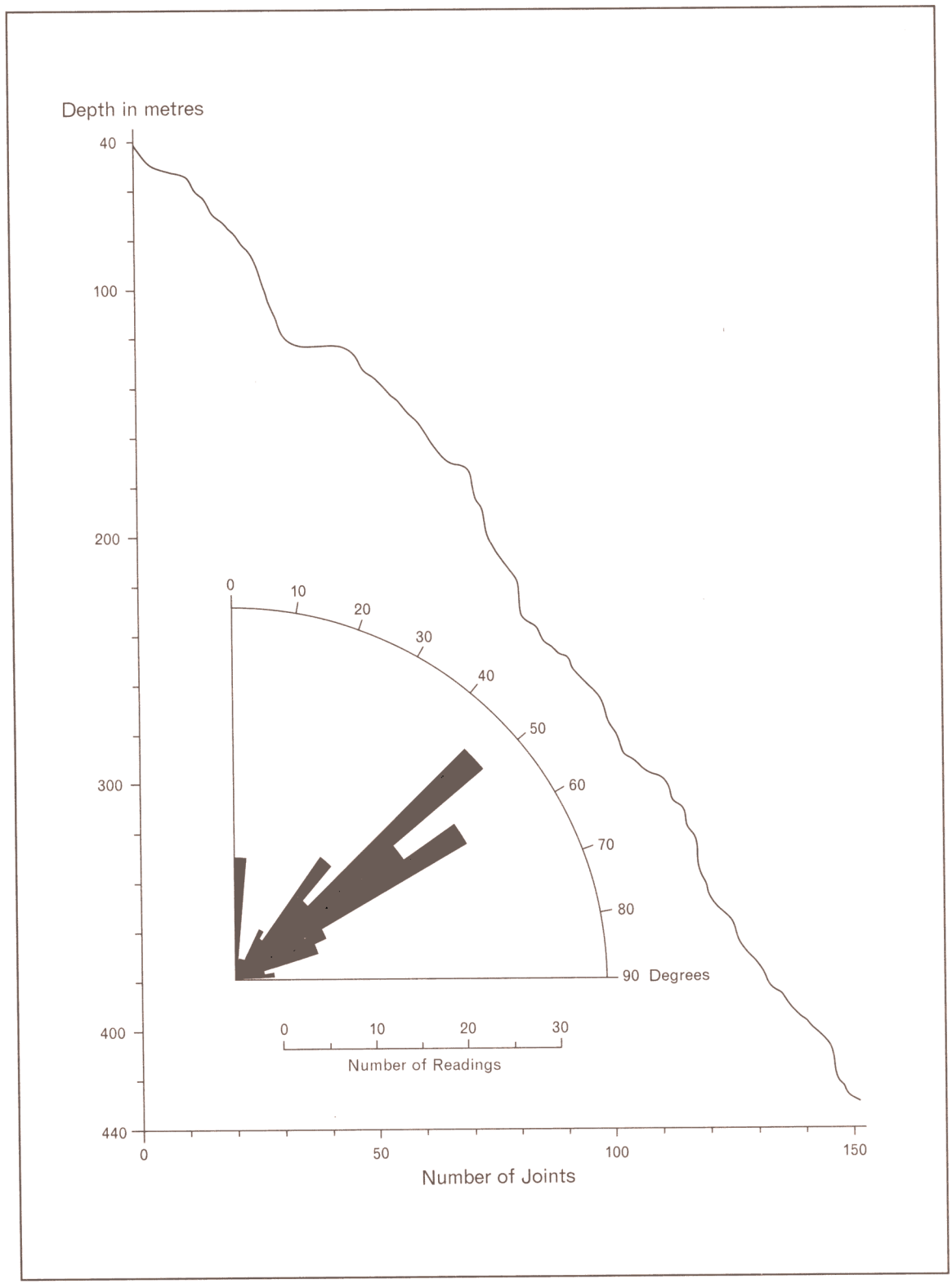

Figure 11 - Graph Showing Frequency and Inclination of Joints in the Ma Tin Road Borehole