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**UNROOFING HISTORY AND STRUCTURAL EVOLUTION OF THE
SOUTHERN LHASA TERRANE, TIBETAN PLATEAU: IMPLICATIONS FOR
THE CONTINENTAL COLLISION BETWEEN INDIA AND ASIA**

by

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A Dissertation

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Department of Geological Sciences

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Figure 4.2 Field photo of the unconformity between the Cretaceous Takena red beds and the overlying Linzizong volcanics. The height of the hillside is about 800 m. Photo was taken near Maqu village, looking NW across the Doilung Qu river valley from the Lhasa-Yangbajain road.

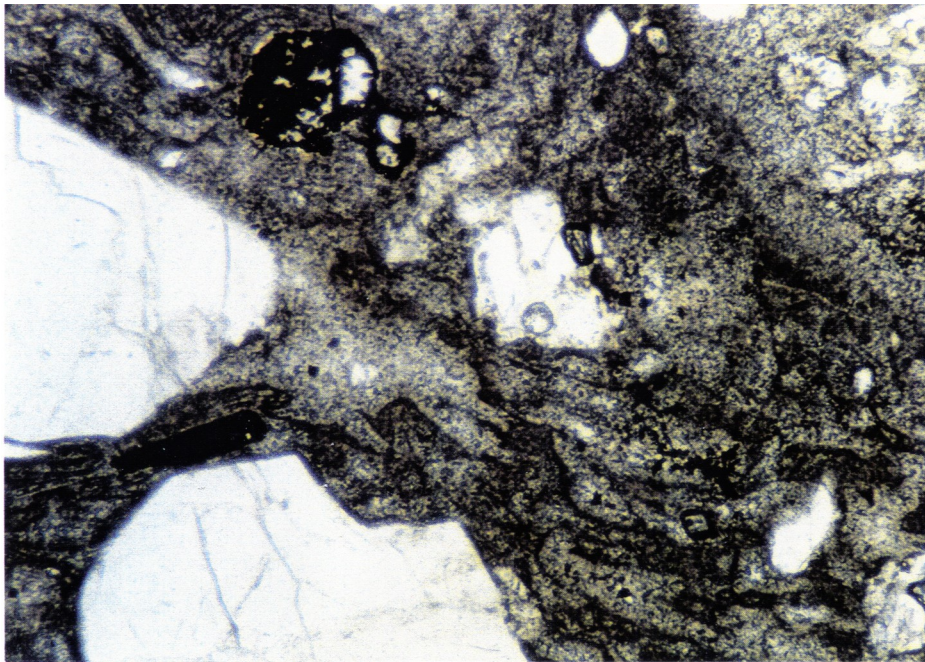
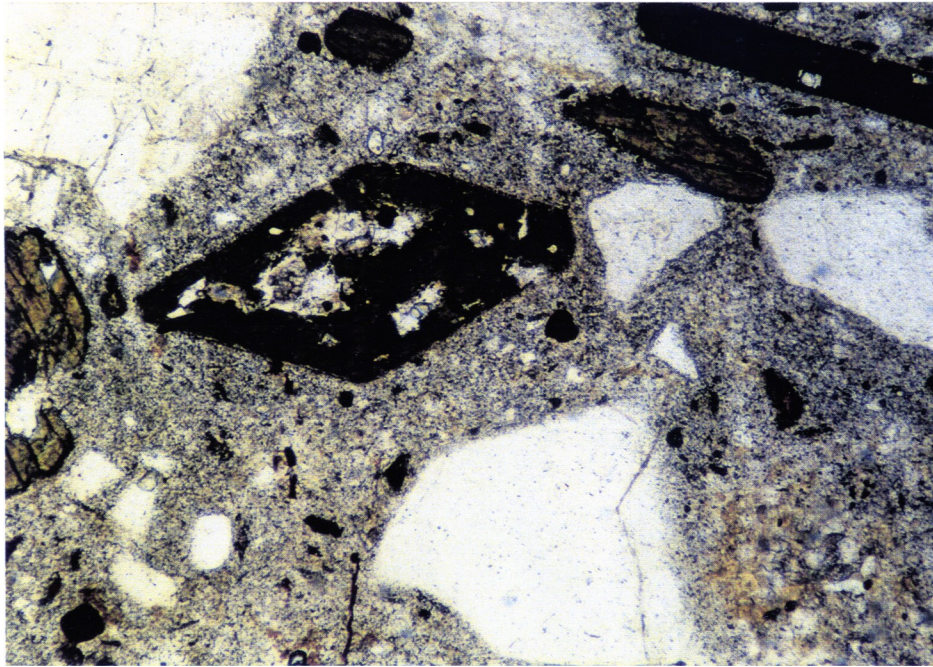


Figure 4.5 Photomicrographs of selected thin sections. Above: K-6-88, dacite. The porphyritic phases are quartz and hornblende. Below: K-10-88, ignimbrite, matrix devitrified. Each photo is 2 mm cross and in plain light.

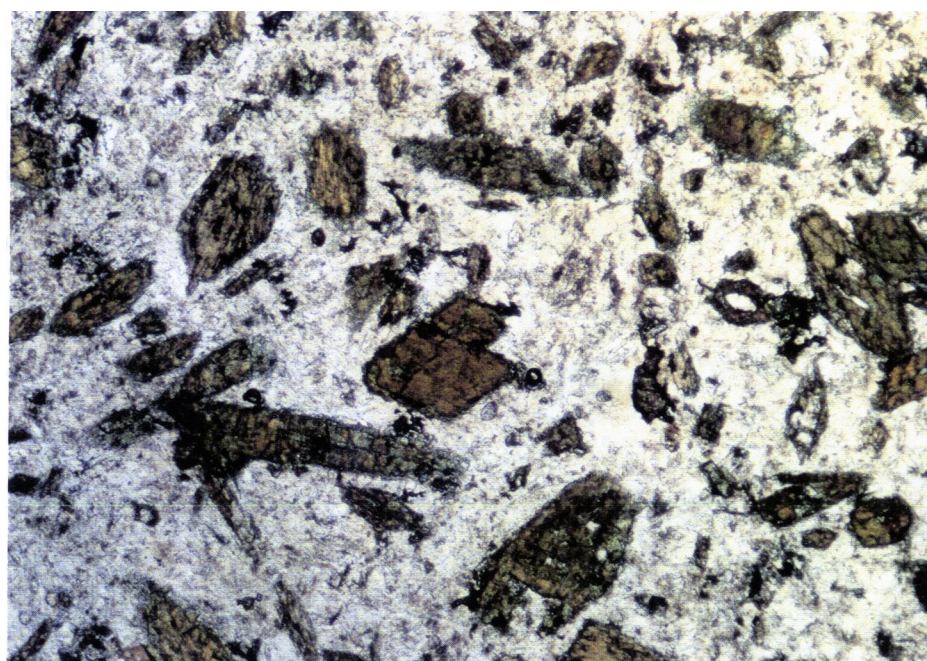
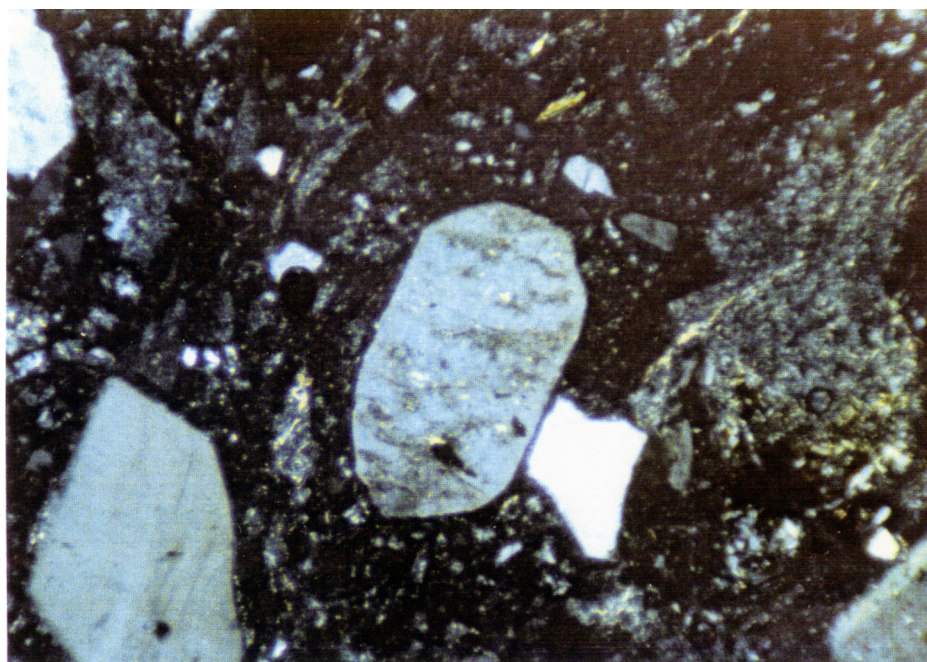


Figure 4.5 Continued. Above: K-22-88, ignimbrite, cross-polarized light. Width of photo is 2 mm. Below: K-47-88, microdiorite, plain light. Width of photo is 3 mm.

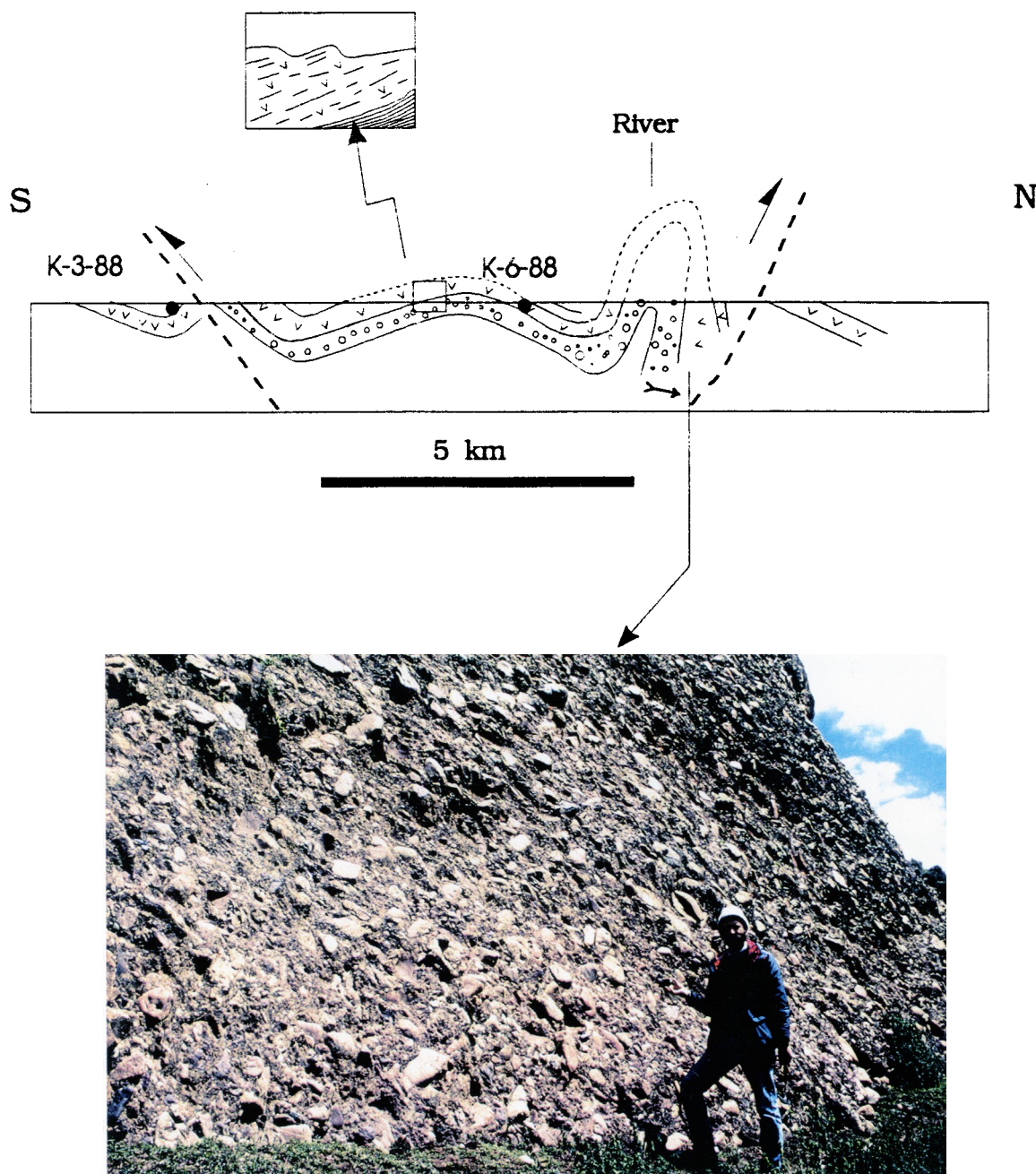


Figure 4.17 **above**: Tentative cross section along Majiang-Dazhuka road, about 20 km west of Majiang. The conglomerate and sandstone sequence is interpreted to be conformable with volcanic tuff and ignimbrite deposits, the detail from a field photo showing the contact. The sequence is folded, and the bedding and layering are locally vertical and slightly overturned to north as suggested by cross bedding and graded beds. **below**: Field photo showing the vertical dipping conglomerate. See text for discussion.



Figure 4.18 Field photo showing the diorite stock (K-33-88) cutting the folded Tadena sediments. South of Maqu, west of the Doilung Qu river.

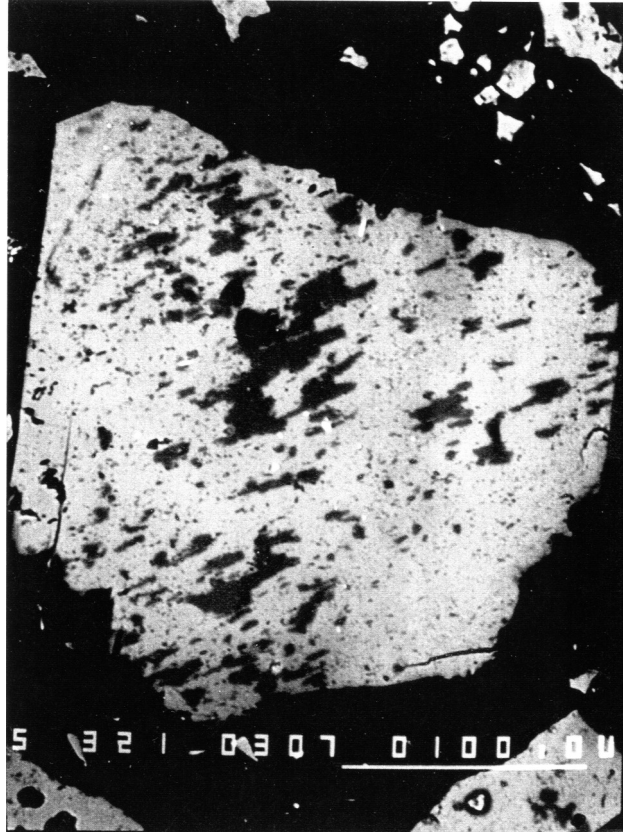


Figure 4.20 Perthitic albite in orthoclase. Back-scattered image, scale bar is 100 microns.

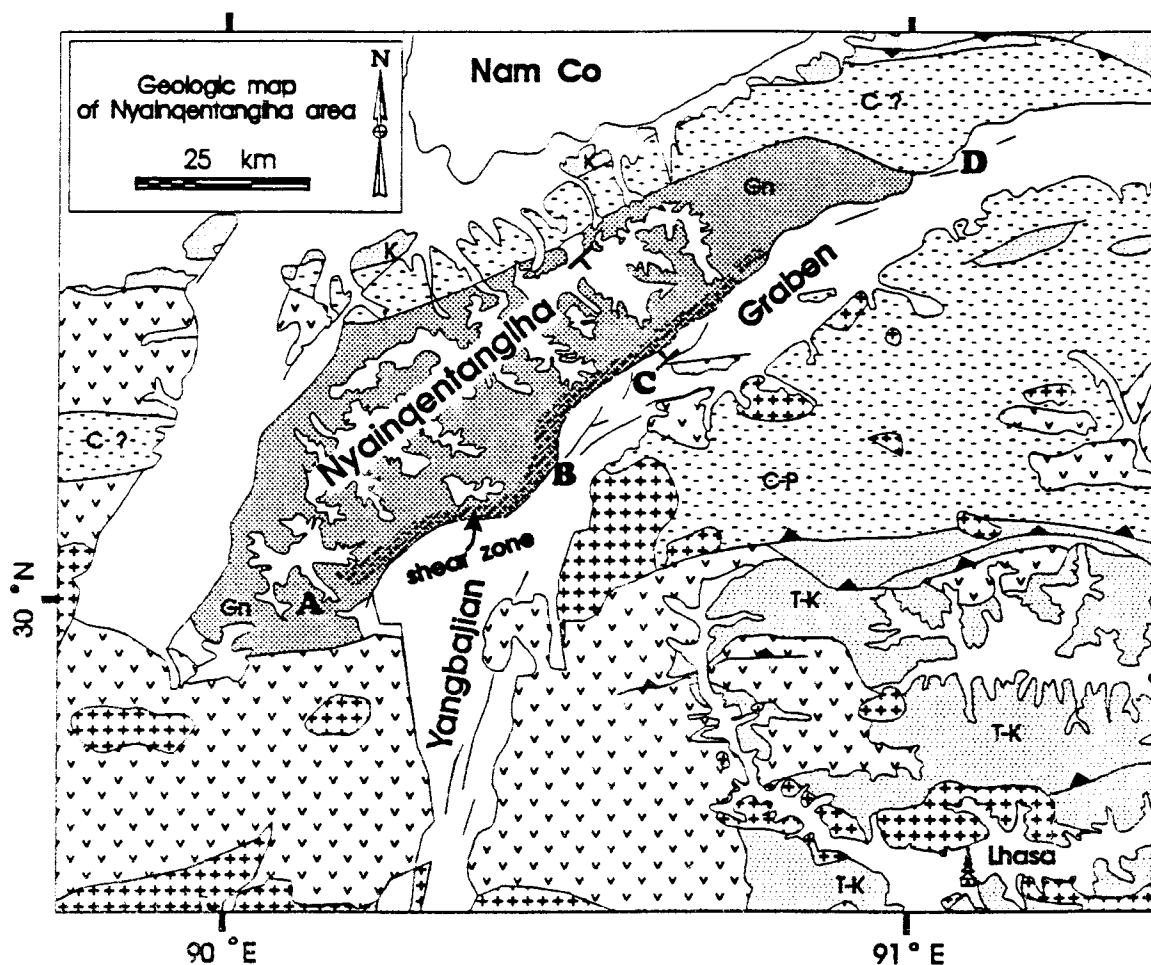


Figure 5.2 Geologic map (after Kidd et al., 1988) of the Nyainqentanglha area, southern Tibet. Patterns and symbols: + = Gangdese batholith, v = Cenozoic volcanics, Gn = orthogneisses, C ? = possible Carboniferous sedimentary strata, C-P = Carboniferous-Permian sedimentary strata, T-K = Triassic-Cretaceous sedimentary strata. Lines with teeth are thrusts. Darker band on the southeast boundary of the area of orthogneisses represents the Nyainqentanglha shear zone. Blank areas are either Quaternary sediments, or ice cover in the Nyainqentanglha range.



Figure 5.3 Field photos of the NQTL shear zone. **a**: An outcrop at location C (Parnulang valley) of Figure 5.2. The height of the cliff is about 300 m. **b**: Detail of this outcrop showing S-C foliations. The horizontal length of the photo is about 16 cm. All looking NE.

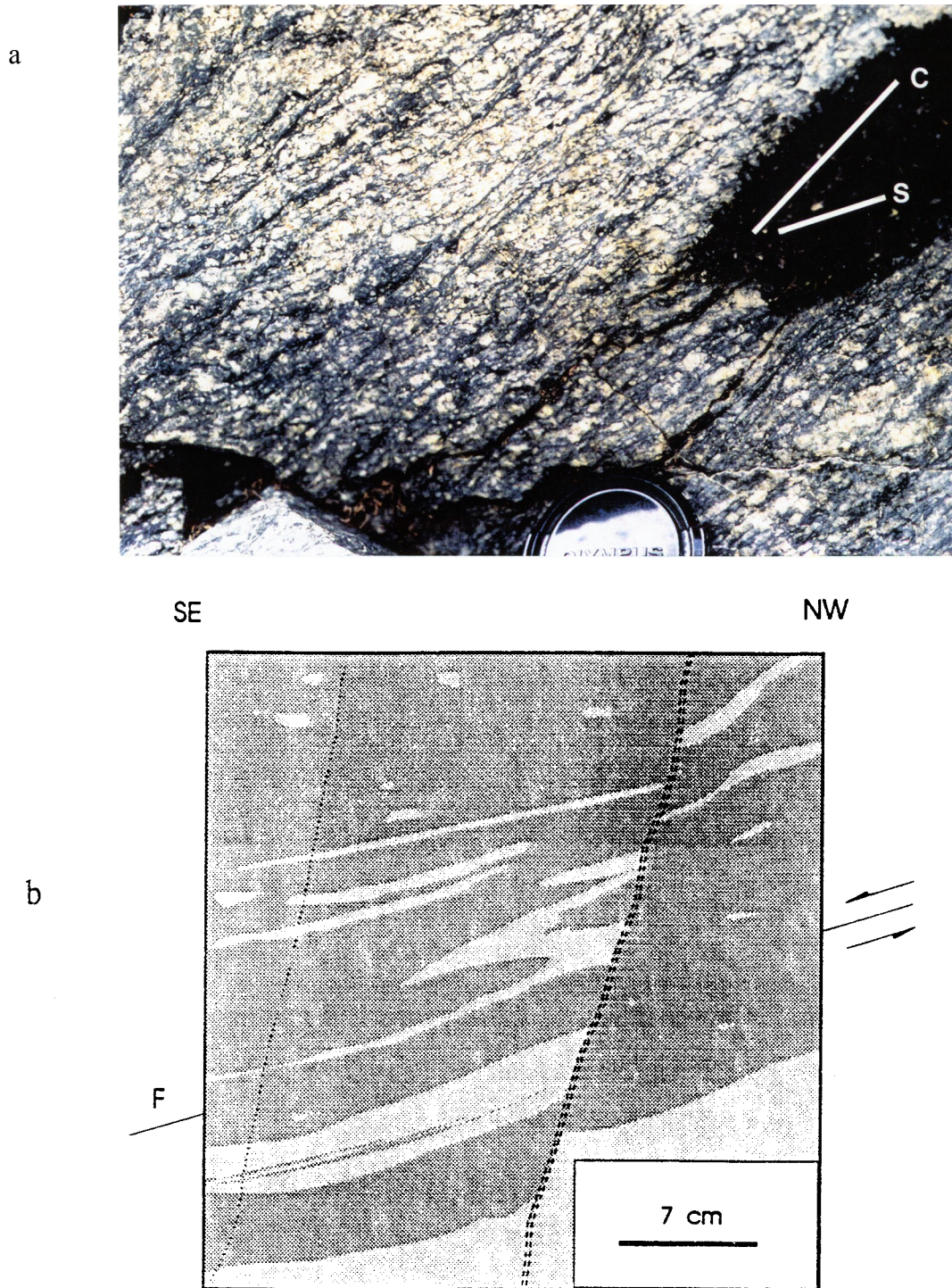


Figure 5.4 Field observations at Goring-la valley (location B of Figure 5.2). a: An outcrop photo showing foliations of the NQTL shear zone, looking southwest. b: Asymmetric intrafolial fold sketched from a field photo, looking southwest. The white areas are richer in quartz and feldspar compositions. F = foliation.



Figure 5.6a Looking north from near Yangbajain village across the Yangbajain graben at Nyainqentanglha mountains (photo by Bill Kidd). Low-angle triangular facets formed by dissection of Nyainqentanglha shear-zone dip slope are prominent in geomorphology of southeastern margin of the range. High-angle master normal fault of the active graben is present in moraines forming the edge of the range.

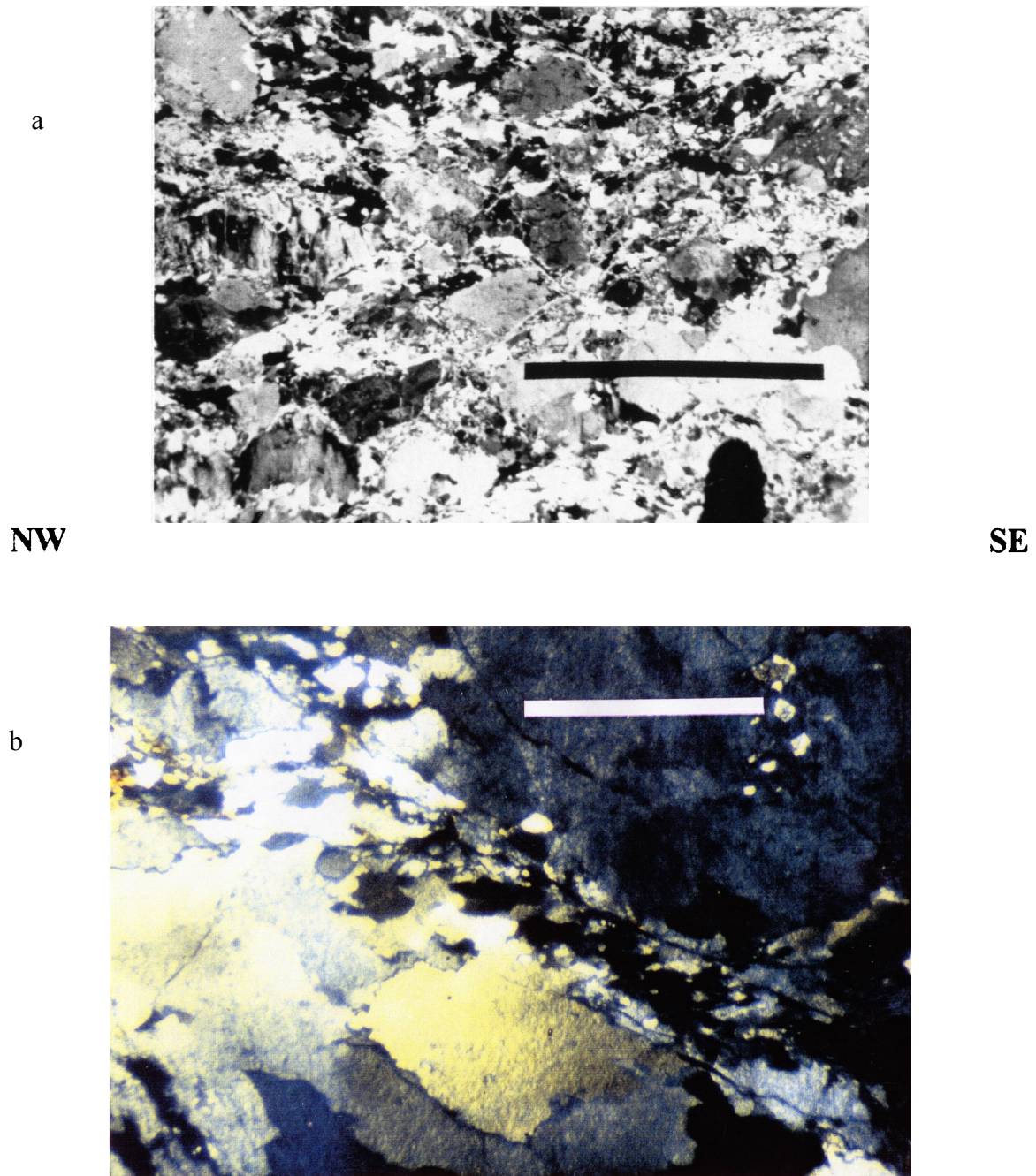


Figure 5.8 a: Photomicrograph of a least deformed sample (P-74), showing large feldspar and quartz grains. Scale bar = 1 cm. b: Details of an enlarged portion of the same sample showing deformation features of quartz. Scale bar = 1mm, Cross polarized light. Sections are cut parallel to the XZ plane, and looking NE.

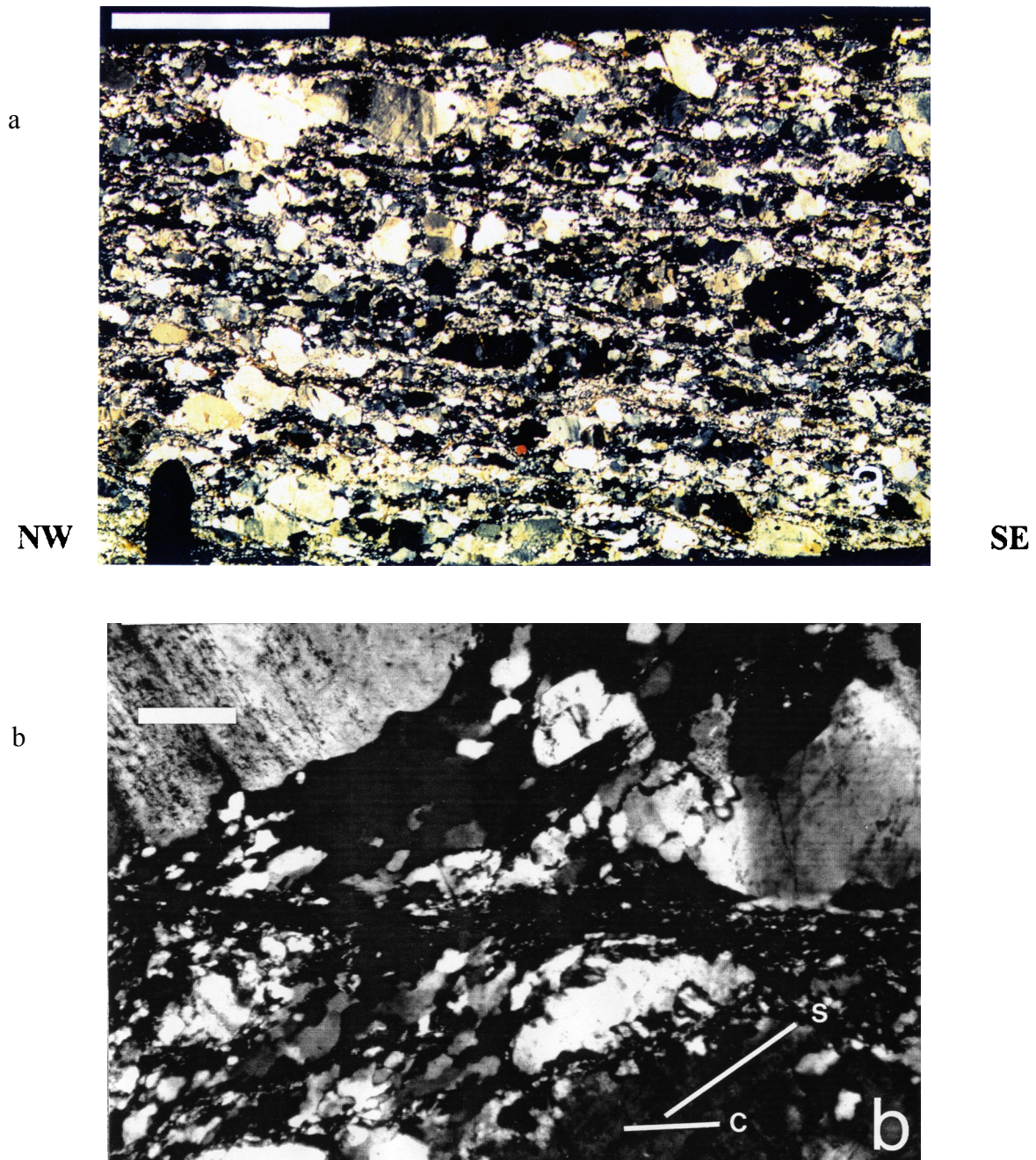


Figure 5.9 Photomicrographs of mylonitic granites (P-28-1 and P-28-2). **a**: The entire view of the thin section (scale bar = 1 cm). Notice the grain size is reduced relative to the weakly deformed sample (P-74), The shearing foliation (the C planes) is well developed. **b**: S-C relations indicating a top-to-southeast sense of shear, scale bar = 0.25 mm.

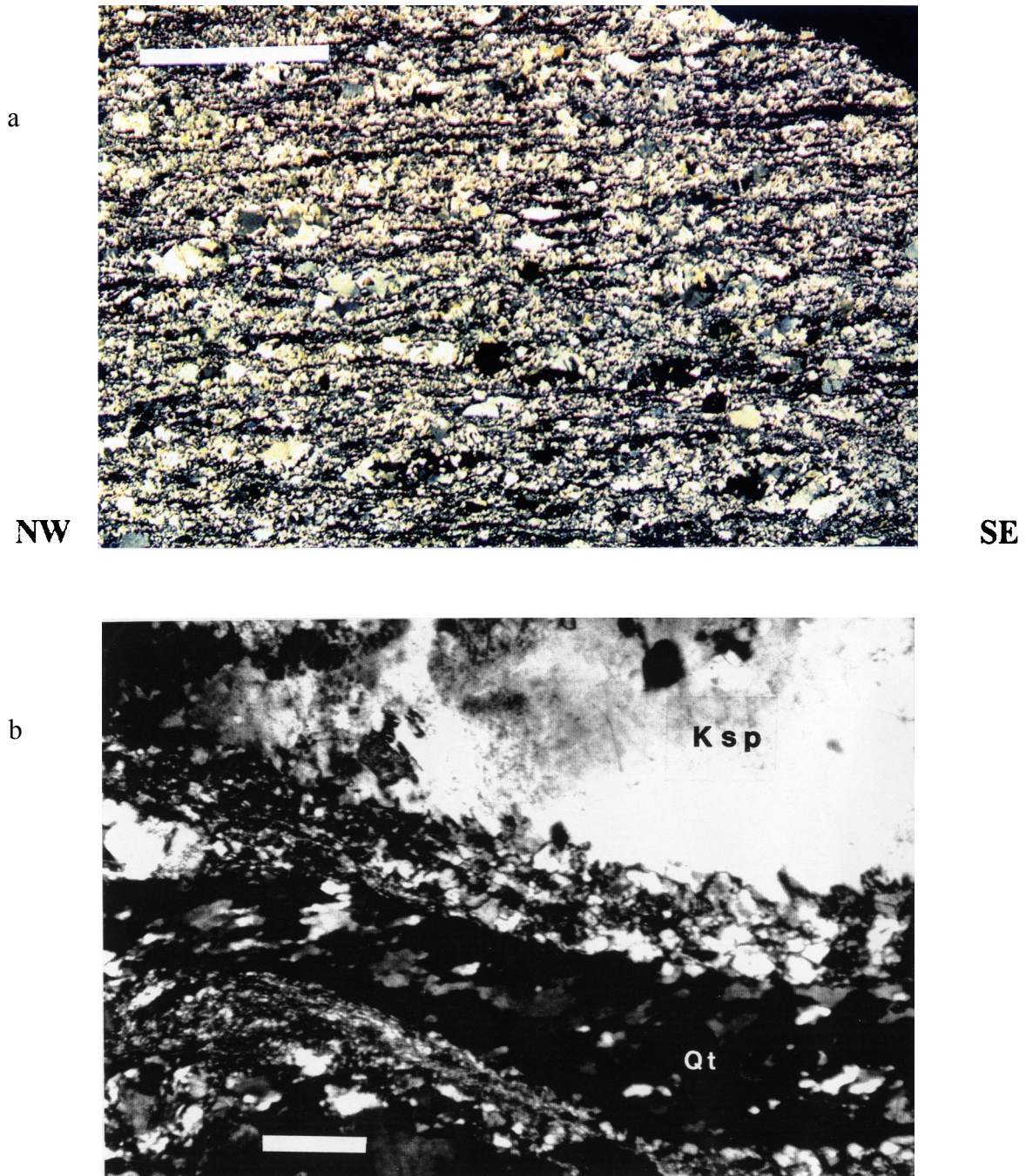


Figure 5.10 **a**: Strong shearing foliation C and reduced grain size in mylonite (scale bar = 1 cm). **b**: Down-stream imbrication of recrystallized quartz (Qt), displaying characteristic oblique foliation Sq and indicating top-to-southeast sense of shear. Scale bar = 0.25 mm. Ductile deformation of K-feldspar (Ksp), showing recrystallized rim with zigzag shapes. No subgrains present within this grain.

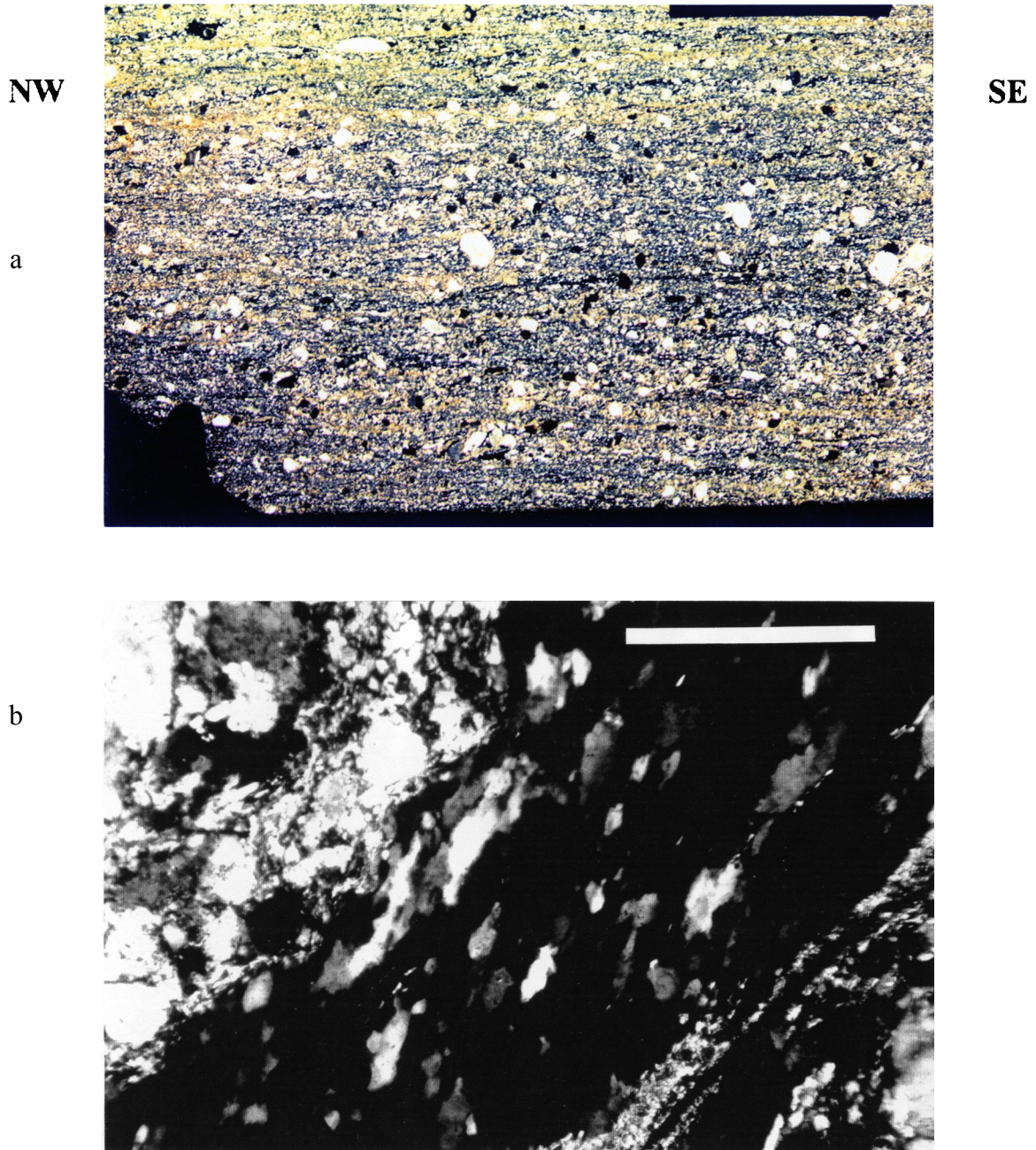


Figure 5.11 Photomicrographs of an extremely fine-grained ultramylonite (P-72-1 and P-72-3), near the top of the NQTL shear zone. All looking NE. **a:** Whole section view (scale bar = 1 cm). Notice the strong shear foliation C, which is horizontal in this photo. **b:** A quartz ribbon (parallel with C, but the picture is rotated such that the ribbon is inclined up to the right) consisting of obliquely aligned quartz grains or subgrains (scale bar = 0.25 mm).

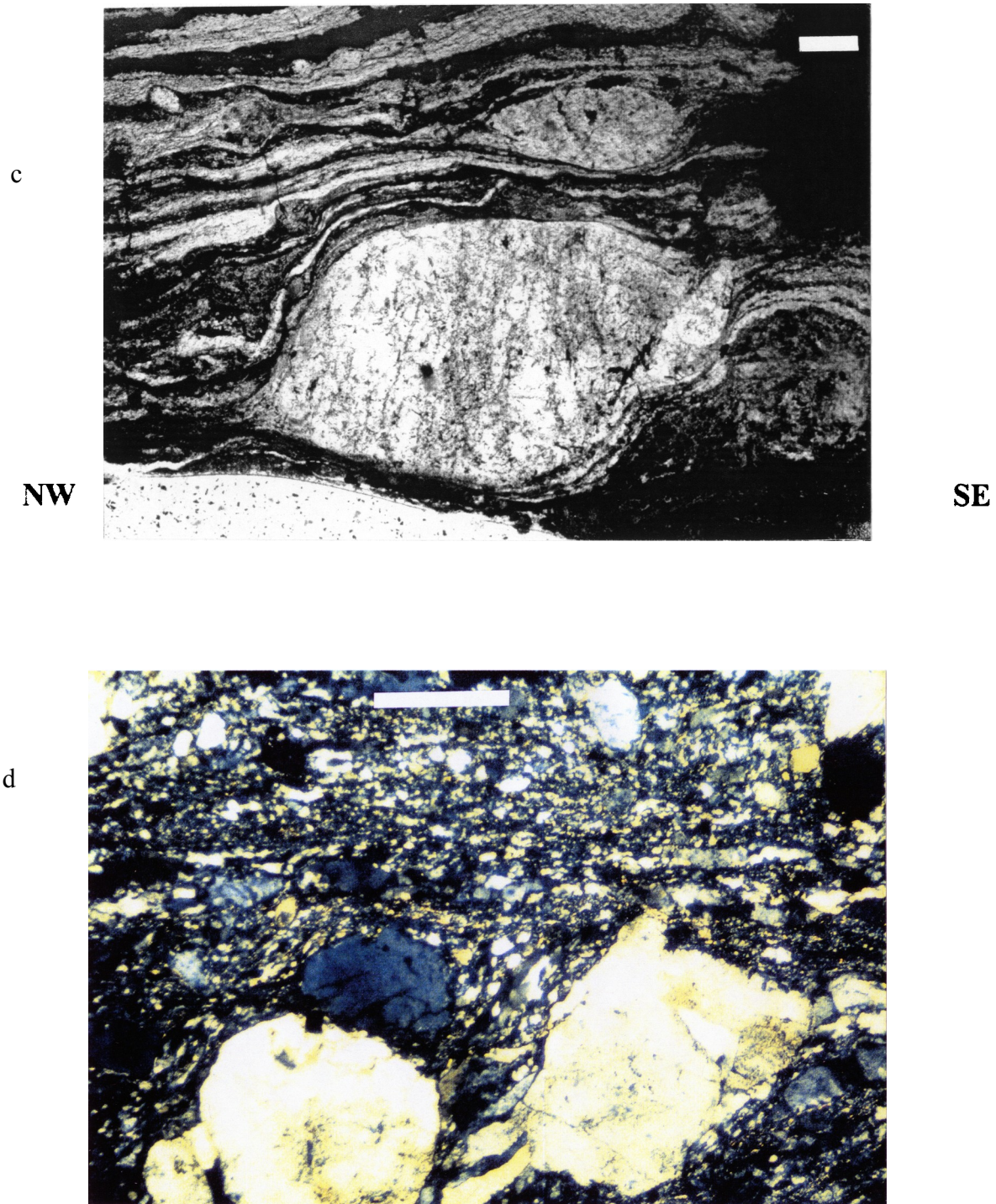


Figure 5.11 Continued. **c**: Sigma-type of porphyroclast feldspar showing a top-to-southeast sense of shear (scale bar = 0.25 mm). **d**: Broken and offset feldspar and quartz filling in between the two broken parts (scale bar = 0.5 mm).

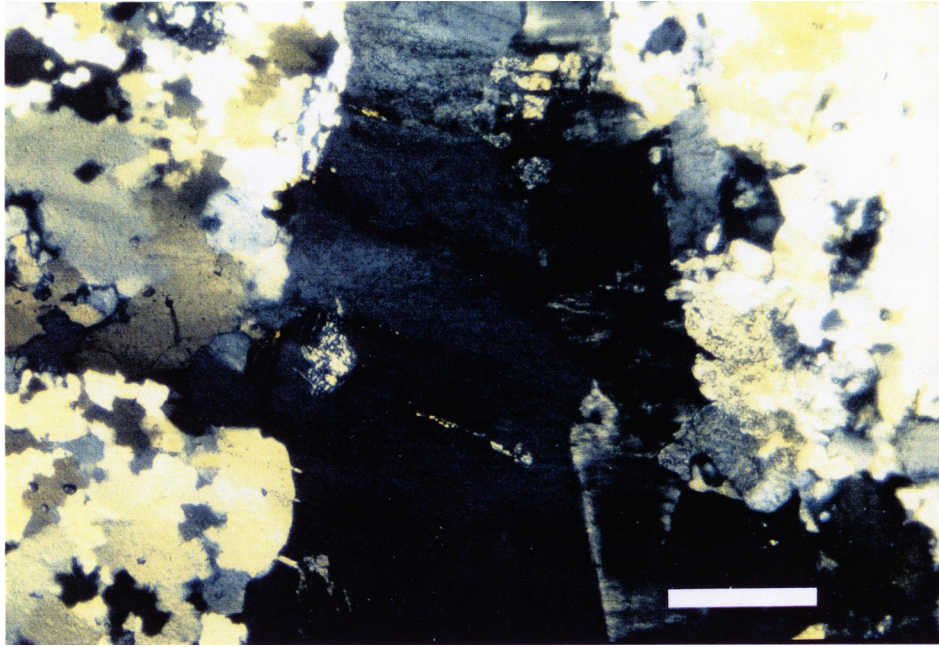


Figure 5.13 Photomicrograph of mineral lineation (vertical in photo) in sample P-28-3. XY section, top is NW. Scale bar = 0.5 mm.

a



b

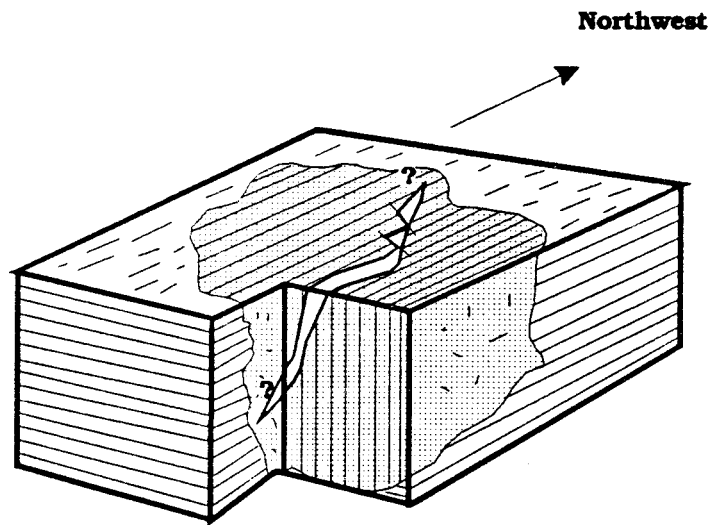


Figure 5.16 a: Field photo showing the leucocratic vein truncates the foliation of a metasedimentary gneiss xenolith-block in NQTL shear zone. b: Sketched diagram showing the relation between the calc-silicate gneiss, the shear zone, and the leucocratic vein.

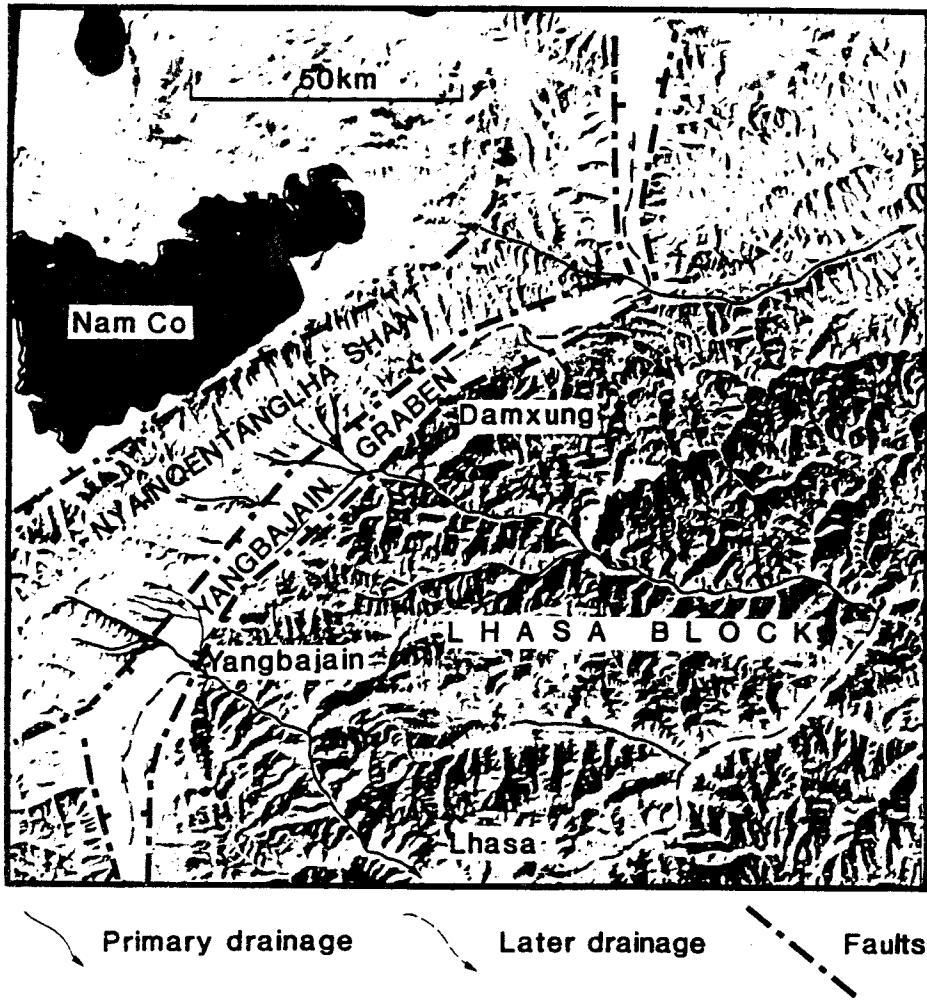


Figure 5.17 Xerox copy of satellite view of NQTL range, YBJ graben, and southern part of Lhasa terrane (adopted from Shackleton and Chang 1988), showing antecedent relation of primary drainage systems and the structural depression of the graben. See text for discussion.

Figure 6.1 Geological map of Maqu area, southern Lhasa terrane, constructed based on field data collected during this study. The regional location of Maqu village can be found in Figure 6.16. The shaded areas represent the late Cretaceous-early Tertiary Linzizong volcanics, the blank areas are either bedrock of the Cretaceous Takena Formation, or Quaternary sediments in valleys. Structural observations along the section line a-o are discussed in detail in this Chapter.

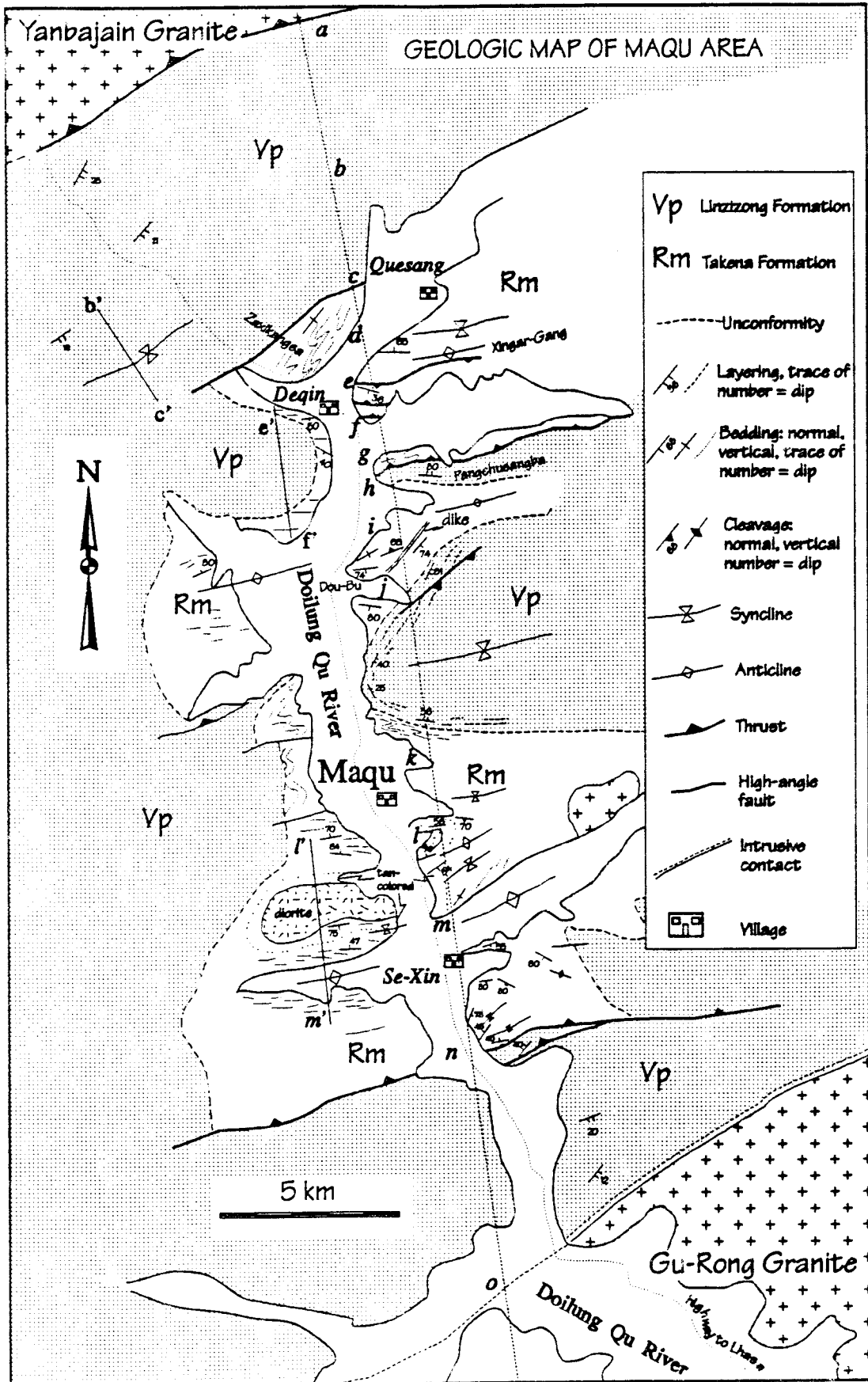




Figure 6.4 Field photo looking NNE at the Zaxikangsa ridge. Notice the gentle dipping volcanic layers (indicated by the white line) at the upper part of hillside.

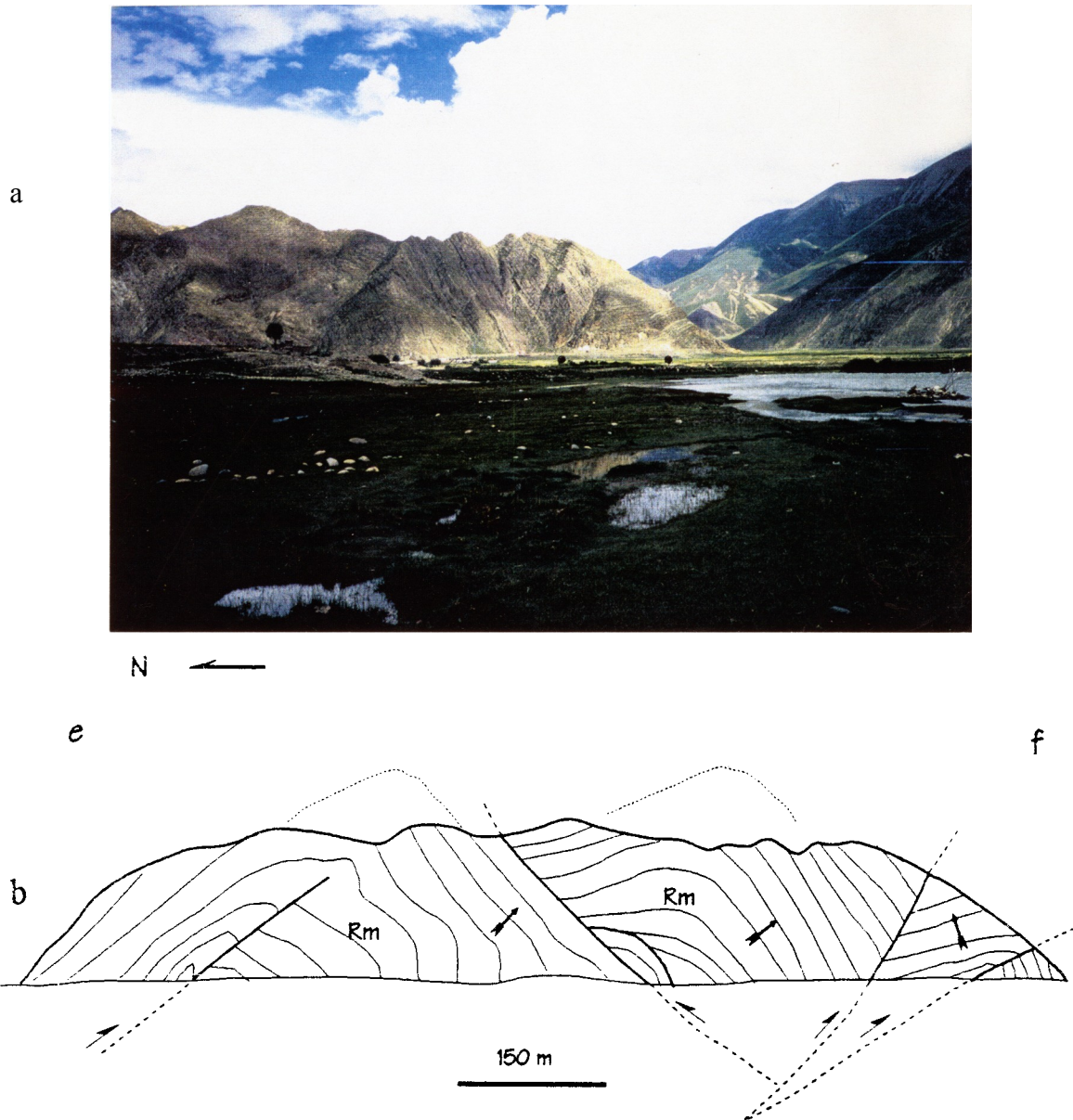


Figure 6.6 a: Field photo of the e-f section (Xingar-Gang ridge), looking east. b: Sketch section (e-f) at the Xingar-Gang ridge. All the rocks exposed here belong to the Takena Formation. The north-directed thrust is interpreted as an early stage backthrust. Dark arrows indicate the younging direction. See text for discussion.

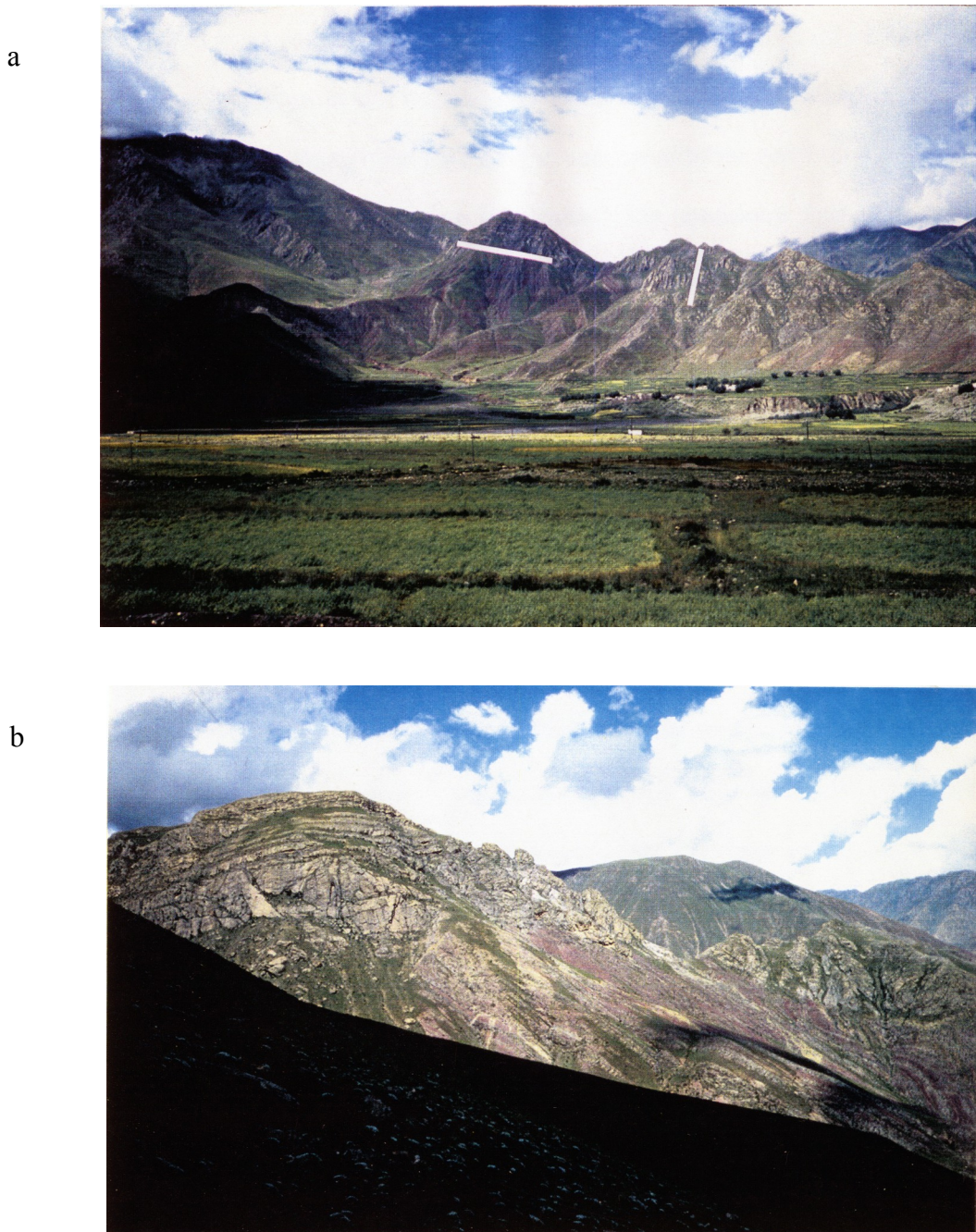


Figure 6.10 **a**: Field photo at a place between j and k looking west across the Doilung Qu River valley, at the tan-colored volcanics above and the red-colored redbeds below. The white line on the left indicates gently-dipping volcanic layers, and the white line on the right indicates near vertical-dipping layers. **b**: A closer view at a place on the west side of the valley, looking at the same outcrops in **a**.



Figure 6.14 Field photo showing a moderately north-dipping thrust fault within the Linzizong volcanics, which is marked by the black bands where the original porphyritic andesite is fine grained with thin layers of pseudotachylite.



Figure 7.4 Field photo showing the magmatic foliation in a granodiorite. Flattened dark enclaves define the foliation. The height of the photo is about 2 m.



Figure 7.5 An outcrop photo, looking east, showing S & C foliations of the mylonitic granodiorite from southern part of the Jiang Qu shear zone. The sense of shear is top-to-the-left (north).

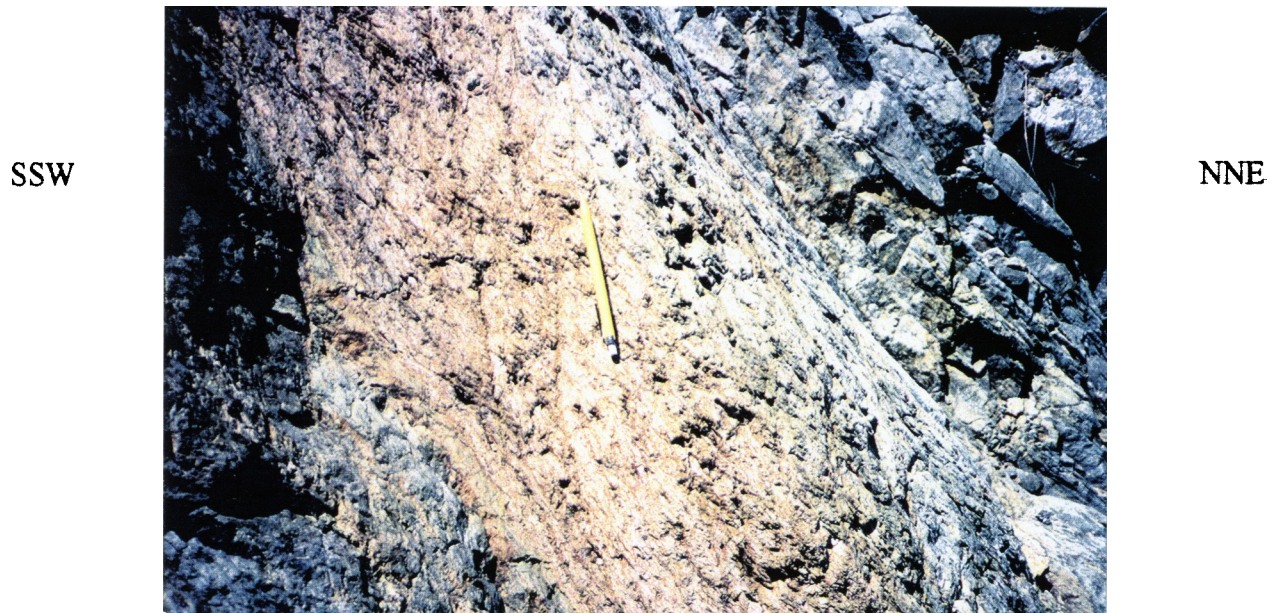


Figure 7.7 Field photo showing the greenschist mylonite; the view is to the WNW. The shearing foliations (S and C) dip steeply to north, and vertical, spaced, shear bands (C') are present. The details are shown in Figure 7.8. The pencil in the center of the photo is about 14 cm.

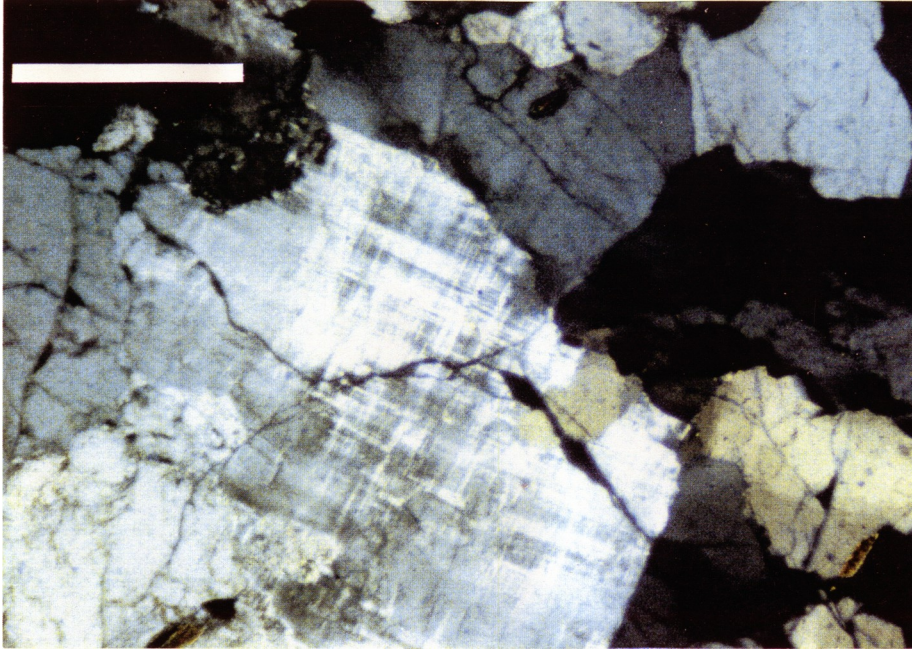


Figure 7.9 Photomicrograph of coarse-grained granodiorite (S-16-3), Quxu. Scale bar is 0.75 mm.

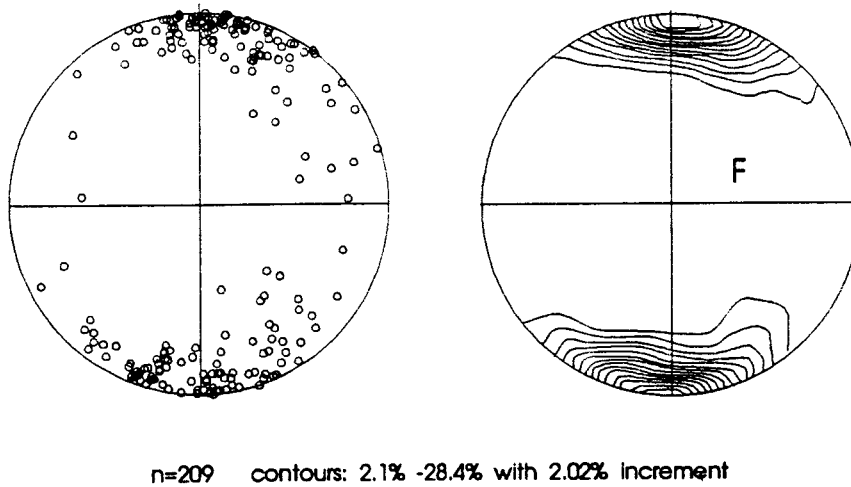


Figure 7.10 Poles to the cleavage of biotite (S-16-2). The data are plotted relative to the plane defined by dip and strike of the foliation (F). Left: points plot. Right: contours plot.

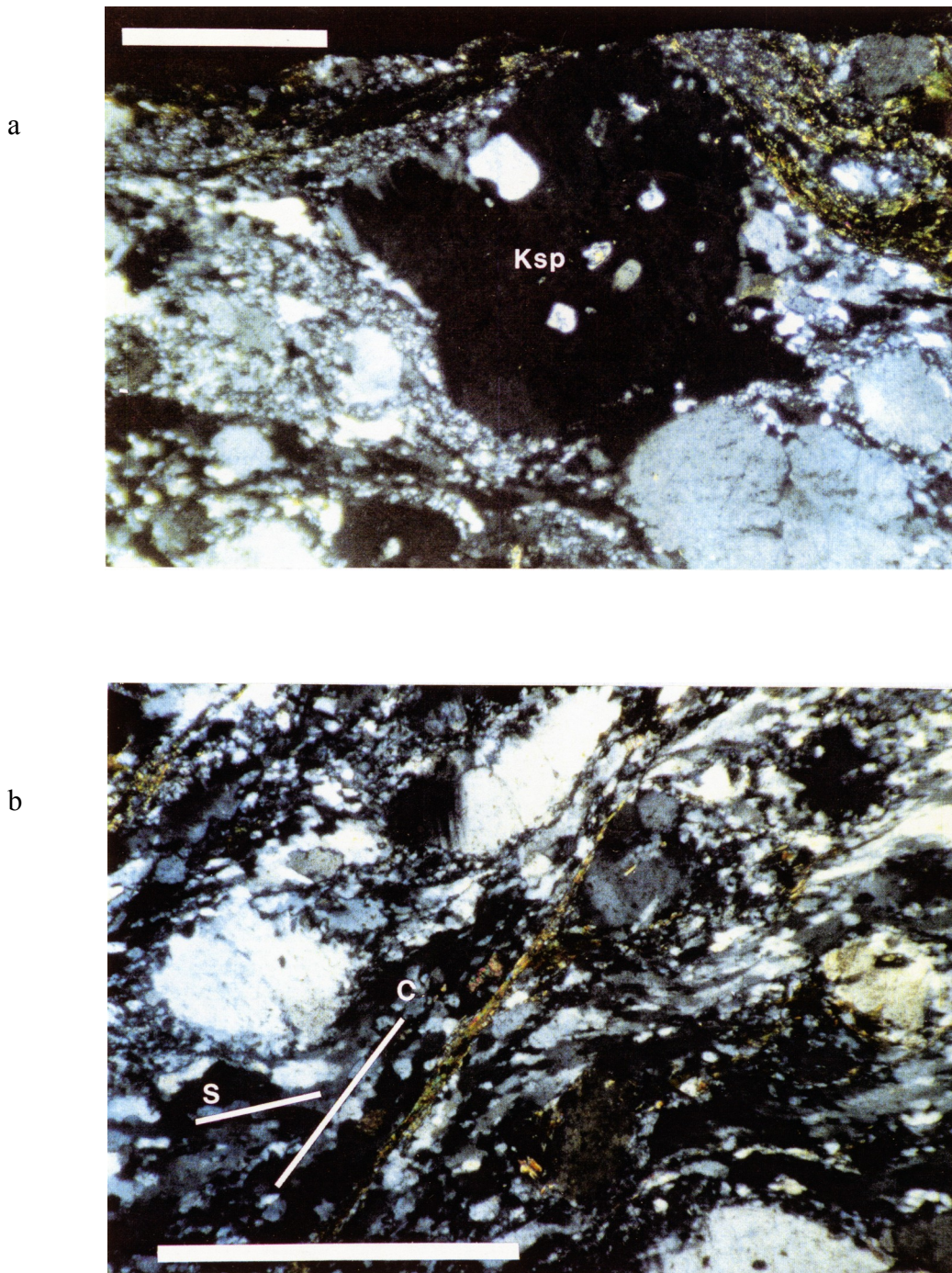


Figure 7.13 Photomicrographs of mylonitic granodiorite, looking east. **a**: Sigma-type porphyroblast of a K-feldspar. **b**: S-C foliations. Scale bar is 0.75 mm in both photos.

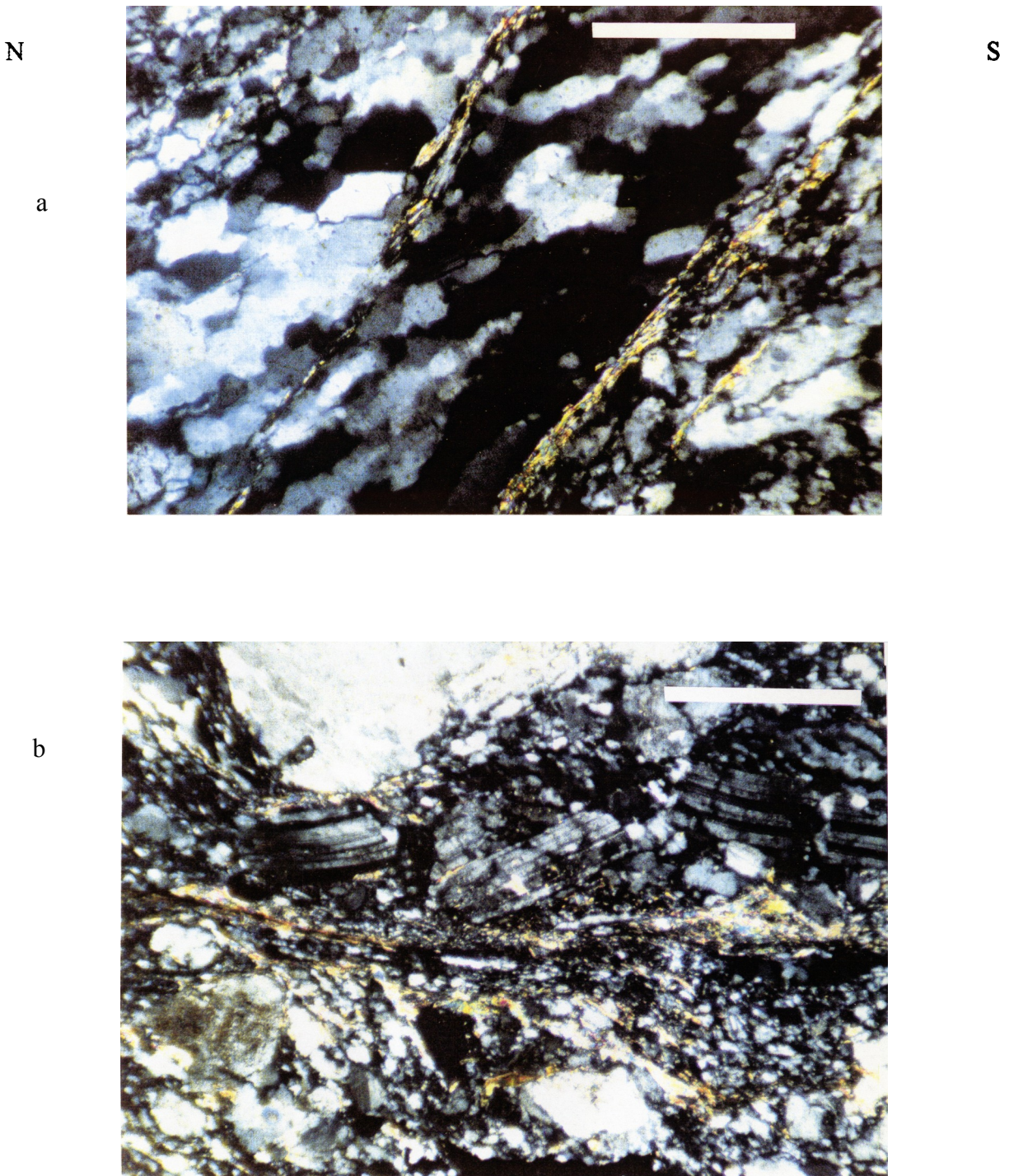


Figure 7.15 Photomicrographs of sheared granite, looking east. **a:** Recrystallized quartz with a shape preferred orientation. Scale bar = 0.2 mm. **b:** Fine-grained feldspar and bending of albite twin. Scale bar = 0.5 mm.

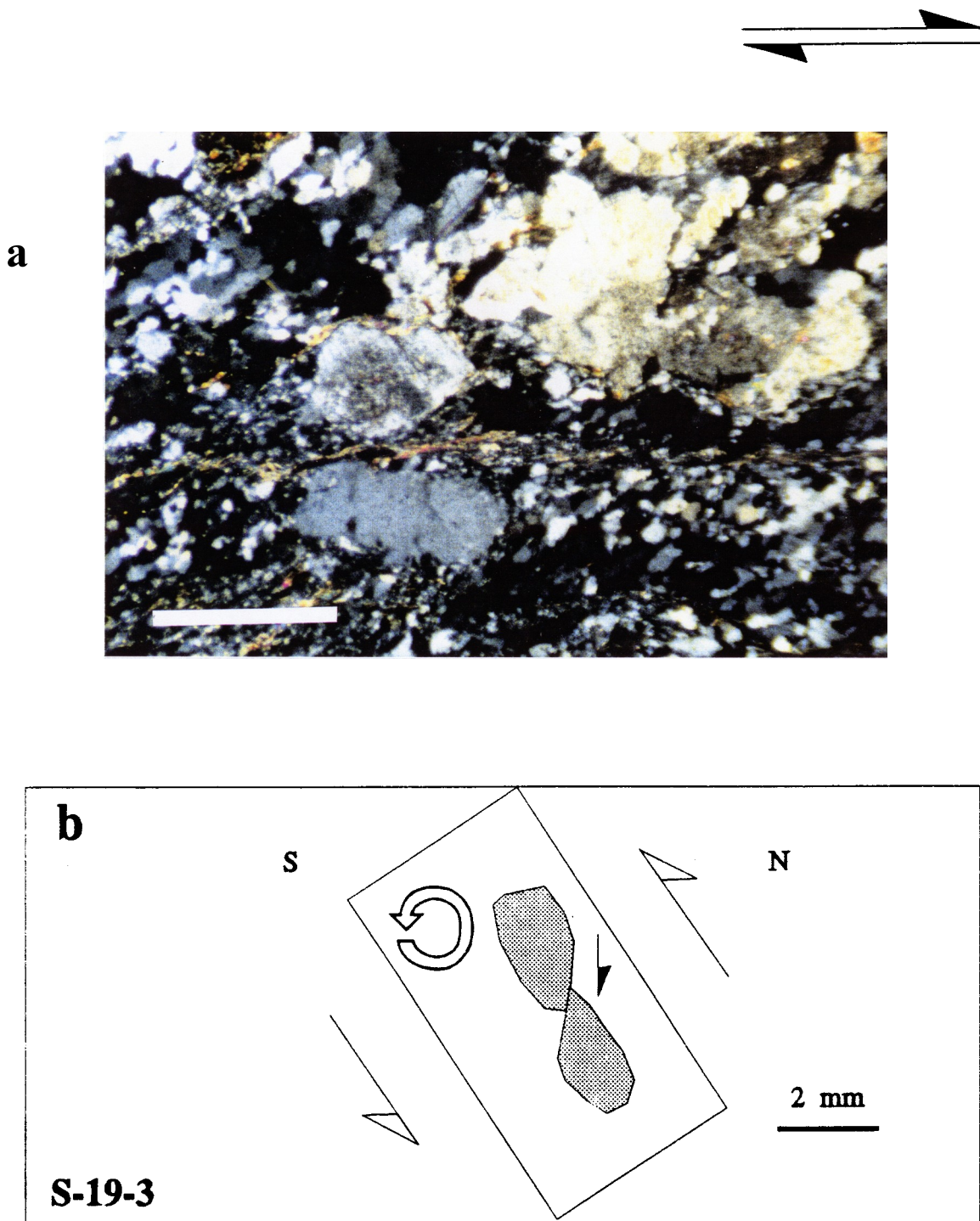


Figure 7.16 a: Photomicrograph showing S-C foliation relation, looking west. The mineral foliation S is inclined up to the right (north), and C is horizontal, indicating a top-to-north sense of shear. b: Sketch of a fractured and rotated feldspar which suggests a thrusting (top-to-south) sense of shear.

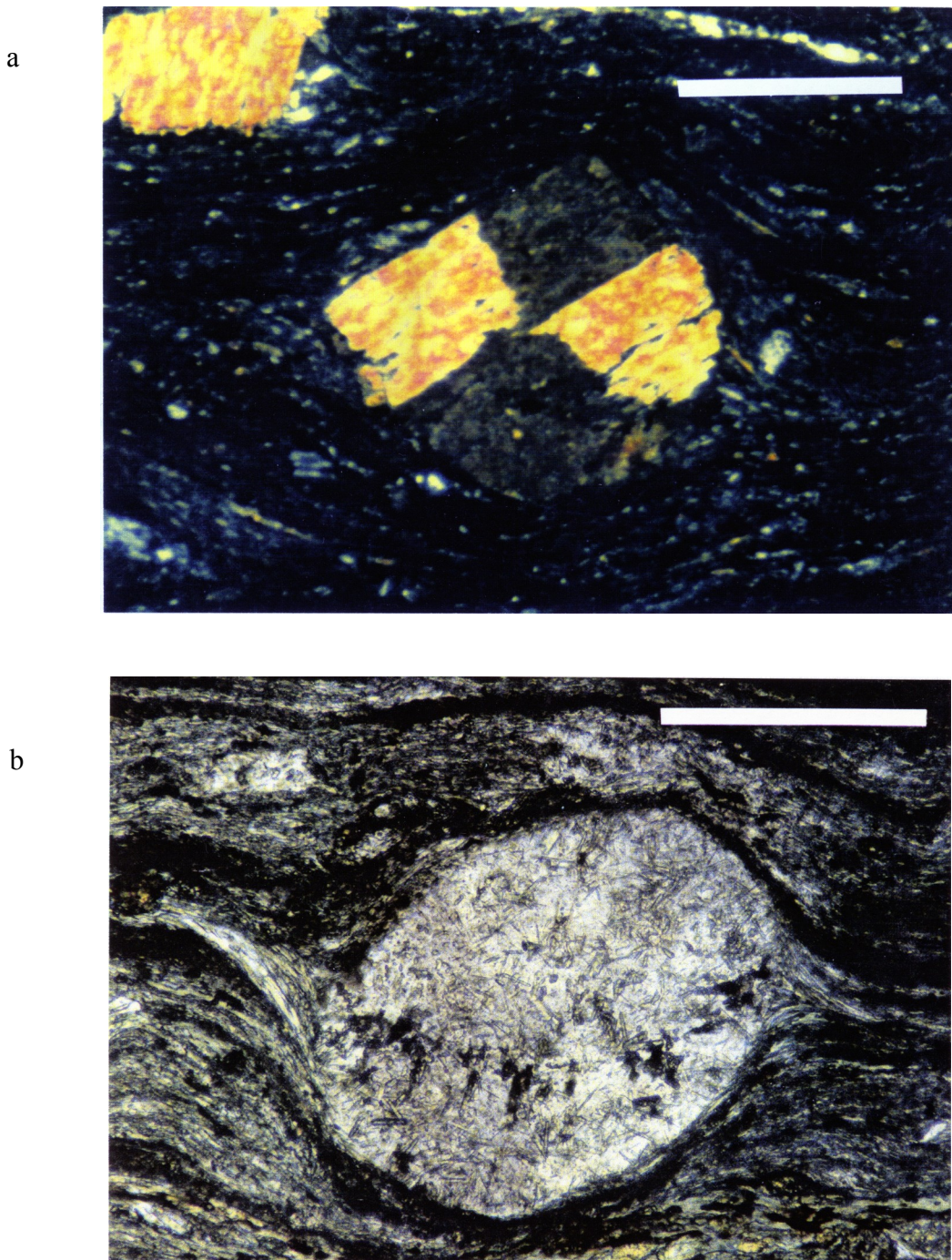


Figure 7.17 Photomicrographs of phyllonite in the northern part of Jiang Qu shear zone. All are looking east. **a**: Relic-shape of sector-zoning of an original clinopyroxene crystal, now transformed to actinolite. Scale bar = 0.75 mm. **b** δ -type feldspar porphyroblast, indicating a top-to-left (north) sense of shear. Scale bar = 0.25 mm.

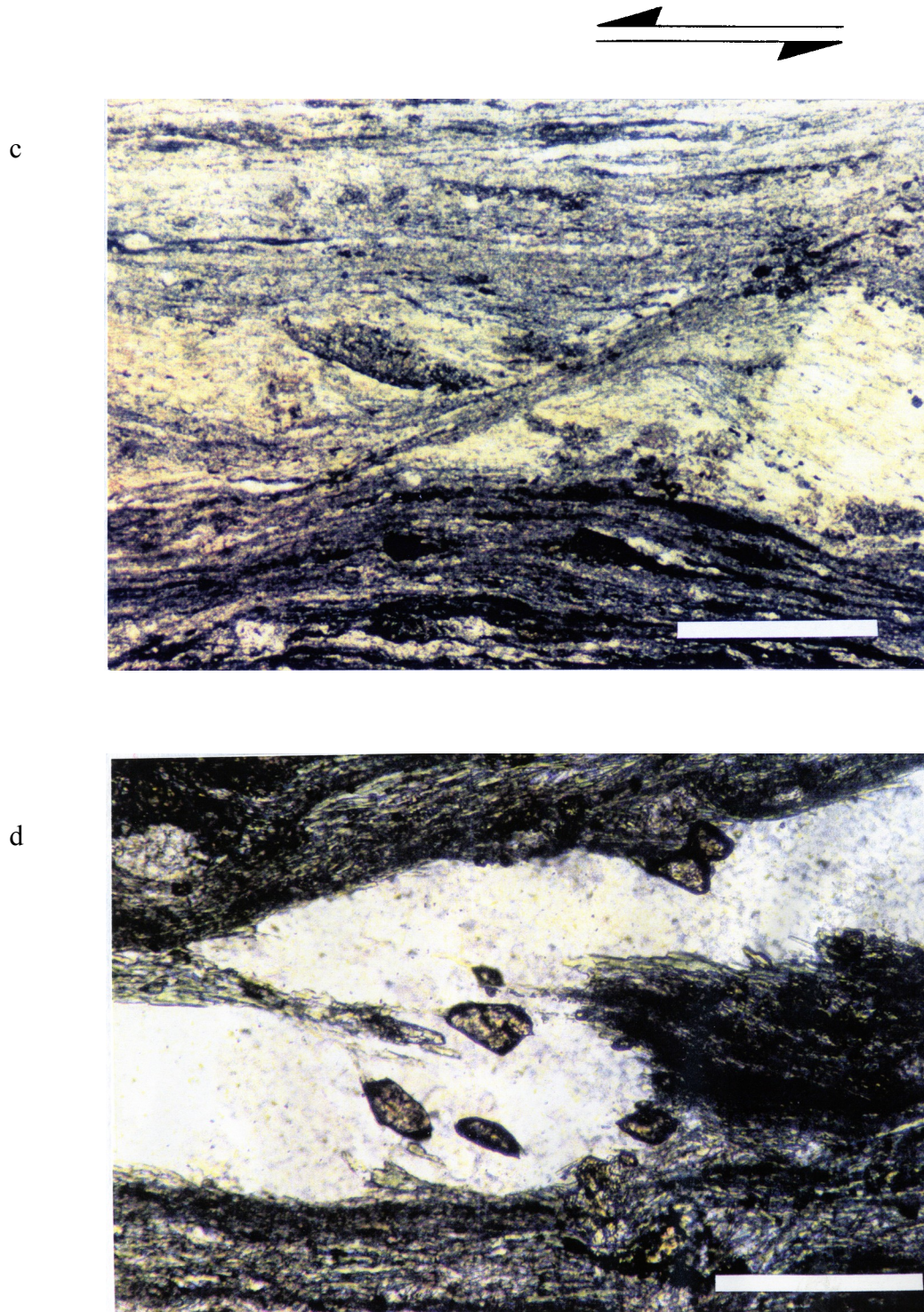


Figure 7.17 Continued. **c**: A later shear band (C') in the mylonitic greenschist. Scale bar = 0.75 mm. **d**: An asymmetrically folded quartz vein in the mylonitic greenschist. Scale bar = 0.2 mm. A top-to-left (north) sense of shear is indicated by both photos.

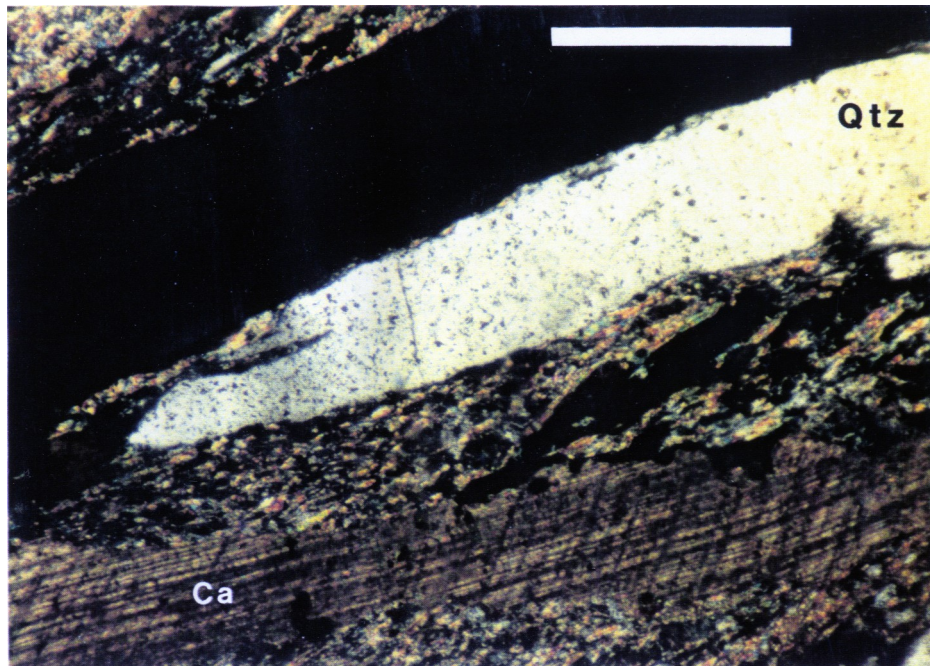


Figure 7.18 Quartz (Qtz) and carbonate (ca) ribbons of a mylonite. Scale bar = 0.5 mm.

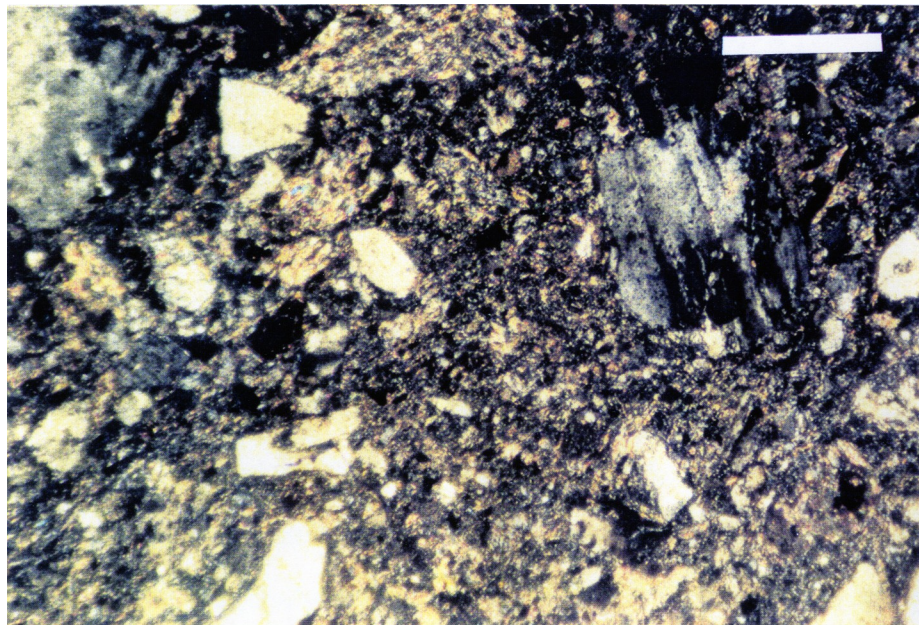


Figure 7.19 Cataclasite in the greenschist rocks near the fault contact at north margin of the Jiang Qu shear zone. Scale bar = 0.5 mm.