

Surface textures of quartz grains from a core at the Prydz Bay, Antarctica*

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Abstract In this paper, shapes and surface textures of quartz grains in 13 layers of a core (NP95-1) collected from a continental slope at the Antarctic Prydz Bay were quantitatively and statistically analyzed. The quartz grain surfaces exhibit the characteristics caused by intense glaciation and a weaker chemical solution-precipitation, indicating the sediments are mainly morainic debris under a low energy marine environment. The obtained quantitatively statistical results of the assemblages of surface textures caused by the chemical solution-precipitation are well correlated to the analytical results of micropaleontologic analysis and can be used to better explain the changes of sedimentary environment and paleoclimate occurred in the marine zone concerned.

Key words Antarctica, quartz grains, surface textures, quantitative statistics, sedimentary environment, paleoclimatic change.

1 Introduction

Different transport mode or different sedimentary environment caused quartz grains to assume different shapes and surface textural features. Their shapes and surface textural assemblages provide a sound basis for analyzing the sedimentary environment and inferring their transport history. Some research work (Culver *et al.* 1983; Williams and Thomas 1989; Haines and Mazzullo 1988; Whalley and Krinsley 1974; Xie *et al.* 1984) has reconstructed the sedimentary environment and evolutionary history by using quartz surface textures caused by different genesis and under different climatic conditions by means of scanning electron microscope.

2 Experimental materials and method

A core sample, 172 cm in length, was collected from a continental slope at the depth of 1970 m in the Prydz Bay of Antarctica (66°45.555'S, 74°50.070'E). Thirteen layers were selected from the core sample according to the obtained analytical re-

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sults from mineral X-ray diffraction and micropaleontologic analysis. They are noted in NP2(5 cm), NP7(17.5 cm), NP9(22.5 cm), NP14(35 cm), NP29(72.5 cm), NP31(77.5 cm), NP34(85 cm), NP37(92.5 cm), NP49(122.5 cm), NP51(127.5 cm), NP56(140 cm) and NP67(167.5 cm), where the figures enclosed in above parenthesis means the depths of the sample bottom, and each layer sample is 2 cm long. Thirty quartz grains in 0.125 – 0.25 mm size were selected from each sample through eye microscope and then mounted on aluminum stubs using double-sided adhesive tape after cleaning with dilute HCL, and coated with gold in a vacuum sputtering unit. Each grain was photographically observed by Shimadzu EPM-810Q electron probe microanalyzer and quartz composition and adhering matters were verified with Philips PV9100/75 energy dispersive X-ray analyzer (EDAX). On the basis of the shapes and surface features provided by scanning photographs and the sedimentary paleoenvironment of the Prydz Bay, referring to and modifying the quantitative method used previously by Williams and Thomas (1989), forty representative variables (see Table 1) were selected here to make a semi-quantitative analysis of the quartz surface textures. The analytical approach involves noting the present(1) and absence(0) of each of 40 textures on each grain and then to calculate out the present frequency of each texture.

Table 1. surface textural features of quartz grains

Grain shape	Physical feature	Chemical features
1 Very angular	15 Large conchoidal fractures($>40\ \mu\text{m}$)	31 Solution pits and crevasses
2 Angular	16 Medium conchoidal fractures($20 - 40\ \mu\text{m}$)	32 Oriented solution V-pits
3 Subangular	17 Small conchoidal fractures($<20\ \mu\text{m}$)	33 Honeycomb solution sur-
4 Subrounded	18 Large block	faces
5 Rounded	19 Small block	34 Solution etching
6 Well rounded	20 deep impact pits and depression	35 Solution precipitation
Edge shape	21 dished concavities	36 Dull precipitation surfaces
7 Edge abrasion	22 Mechanical V's	37 Amorphous precipitation
8 Angular edges	23 Parallel cleavage planes	38 SiO_2 crystals
9 Subangular edges	24 Meandering ridges	39 flaking and scaling
10 Subrounded edges	25 Straight and curved grooves	40 Adhering particles
11 Rounded edges	26 Scratches	
Relief	27 Late stage complete grain breakage	
12 High relief ($>1\ \mu\text{m}$)	28 Cracks	
13 Medium relief($0.5-1\ \mu\text{m}$)	29 Upturned flakes	
14 Low relief($<0.5\ \mu\text{m}$)	30 Steps	

3 Results and discussion

3.1 Quartz grain surface features

3.1.1 Quartz grain shapes

In the studied samples, quartz grains in very angular, angular and subangular shapes account for 10% – 30%, 30% – 43% and 13% – 30%, respectively, (Plate II -10,11; III -27; V - 43,46), but the subrounded and rounded shapes only for 10% – 27% and 0% – 13%, respectively. As to the edge shapes, angular and subangular edges account for 23% – 43% and 20% – 43% (Plate I -1, 3, 4; II -10, 11; V -46), subrounded and rounded edges for 7% – 37% and 7% – 23% (Plate I -9; II -17; III -

21, 26). 53% – 87% edges were abraded in varying degrees ; 27% – 60% and 27% – 43% grains in high and medium relief. Generally speaking, grains with clean, smooth surfaces and fresher conchoidal fractures indicate that they were transported for a short distance, and most grains with slightly abraded edges in varying degrees suggest that they were under a cold subaqueous environment.

3. 1. 2 *Mechanical textural features*

The studied quartz grains show following surface textures caused by mechanical collision, compression and abrasion in some transport media, such as wind, glacier and water current.

The very well developed conchoidal fractures exist widely in variable shapes and sizes. Sometimes conchoidal fractures in high, medium and small sizes exist on a same grain and cover more than half of the surface (Plate III -27; IV -33). They may be in convex or concave dish shapes (Plate IV -35–36 or IV -31, 37), and be superimposed each other (Plate IV -32–37), making the grains in angular edges and with irregular protrusions and depression (Plate IV -30, 32–37). The quartz grains in this core exhibit 37% – 94% large—medium conchoidal fractures and 23% – 57% smaller ones, and some conchoidal fractures are very fresh and less etched, indicating that they were mainly caused by a glacial process and subaqueous collision.

The compressions between quartz grains under high energy marine glacial process for a long time may make them to form deep depressions in round and elliptical shapes (Plate I -1, 5; IV -33; V -46) or irregular shapes (Plate I -2–4, 6, 9; III -13; III -28; IV -31, 29, 32, 36); typical aeolian features exhibit are in dish shaped depressions and pits (Plate I -3, 4, 6, 9; III -21; IV -31) and crescent depression (Plate I -6, 7); mechanical V —type pits caused by subaqueous collision and abrasion are superimposed on the textures caused by the glaciation and aeolian origin (Plate I -2–3, 6–8; IV -30–32). Very even cleavage planes caused by rupture along cleavage planes (Plate II -10, 14; III -22) as well as blocks in different sizes are seen (Plate I -3, 7, 8; V -43). There are a series of stepped parallel cleavage planes or parallel plates in same direction (Plate II -11, 12, 15–18; III -22), some of which are fresher (Plate II -12, 16), some are subjected to abrasion (Plate II -17) or solution and precipitation (Plate II -15), some cleavage flakes are upturned (Plate II -12, 13, 15). Some wide and deep scratches can be visible on quartz surfaces, they were caused by compression and abrasion between quartz grains in sharp angular edges during a glacial scoring (Plate III -19, 21, 23, 25), and there are also some fine and shallow striae formed under a subaqueous environment (Plate III -20, 22, 24). Straight and curved impact grooves are marks of a subaqueous environment with medium–high energy (Plate I -6; II -11, 15, 18). Meandering ridges (Plate I -6, 8; II -11, 12, 14) and steps (Plate IV -36) occur normally on convexo-concave surfaces full of impact pits, blocks and grooves along different directions and in different shapes.

Summarily, the mechanical features of quartz grains in the analyzed samples reflect mainly they were subjected to eolian transportation, glacial process and later subaqueous environment with low energy within the provenance, of which the glacial

process has made the grains with especially well-developed and dominant surface textures, namely most grains in irregular shapes and in very sharp edges and ridges; well developed conchoidal fractures and irregular breakages; even or parallel cleavage planes and upturned cleavage flakes; very deep impact concavities and depressions in round and irregular shapes and clear scratches.

3.1.3 *Chemical surface textural features*

Chemical process involves chemical erosion and precipitation. The above mentioned conchoidal fractures, even cleavage planes, upturned flakes and microbreakage between edges caused by percussion and abrasion during glacial process possess active crystal lattice defects, where are optimal sites for chemical process, and are also active centers for redissolution and redeposition of silicon dioxide. In a hot and damp climatic condition, quartz surfaces exhibit oriented V-shaped pits, larger and more solution crevasses, honeycomb textures and flaking, thicker SiO_2 precipitation and more SiO_2 crystals; in a mild-cold climatic condition, quartz surfaces exhibit a weaker solution etching, small etched pits and thin SiO_2 precipitation.

As compared with the very well-developed mechanical features, quartz grains in the analyzed samples show a rather weaker chemical solution-precipitation. The solution etching, etched pits and crevasses as well as oriented V-shaped pits account only for 3% – 43%, 3% – 17% and 20% – 53%, respectively; hardly any honeycomb textures and flaking caused by a serious solution erosion are visible. Solution precipitation, dull precipitation surface, amorphous precipitation and SiO_2 crystals account for 3% – 43%, 7% – 60%, 3% – 33%, 3% – 47% and 0% – 50%, respectively. The above statistical data indicate the core was under a low energy subaqueous environment.

3.2 *Paleoclimate reflected by quartz surface textures*

Generally speaking, the surface textural features of quartz, especially the assemblage of those textures caused by chemical solution-precipitation, can better indicate the paleoclimatic changes. The majority of quartz grains from each layer show smooth, clean and fresh surfaces. Angular and less rounded edges by abrasion, relatively weaker erosion and scattered solution precipitation, as well as thin and amorphous SiO_2 precipitation occurred at conchoidal fractures, steps, parallel cleavages planes and upturned flakes, indicating fully that they existed under a subaqueous environment with low temperature and low energy.

Although the chemical solution-precipitation of the quartz grains was weakly developed, the present percentages of the surface textures reflecting their chemical solution-precipitation are different in the samples as shown in the histogram of quartz grain surface textures (Fig. 1), and their present percentages provide a criterion for interpreting the paleoclimatic changes of the core samples:

(1) NP51-NP59 samples (127.5–147.5 cm): Among all the analysed samples, the grains of those samples show the weakest chemical textures caused by chemical

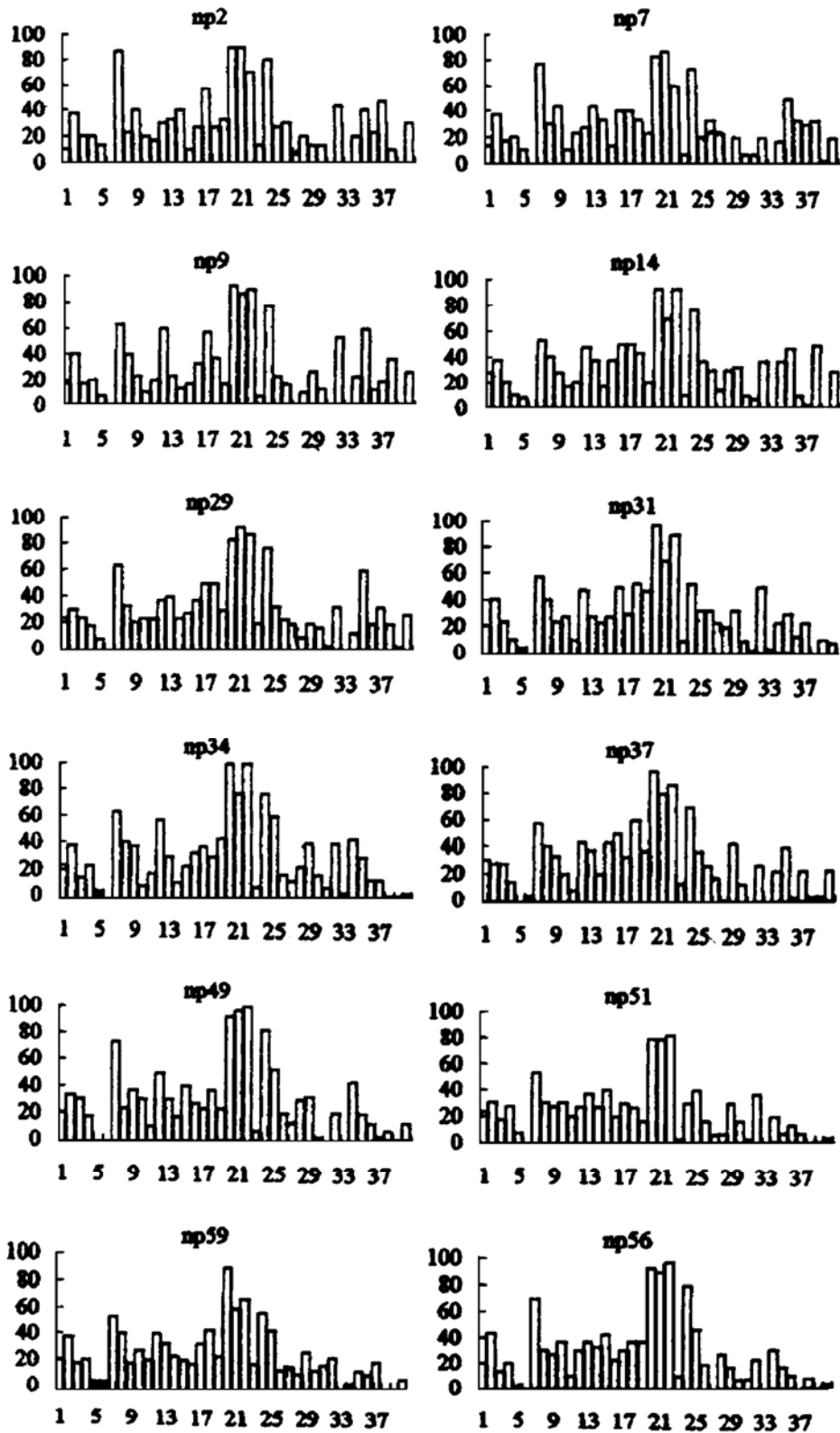


Fig. 1. Frequency histograms of quartz grain surface textures for each sample.

solution-precipitation, which indicates that those samples were under a sedimentary environment with the lowest energy and a frosty climate. Some papers (Luo *et al.* *) indicated that the climate in this period was rather frosty.

(2) NP49-NP37 (122.5–92.5 cm): The chemical solution-precipitation increased continuously, especially flaking and scaling occurred in NP37 and the content of rep-

reservative species of warm water (*Thalassiosira*) increased, indicating a higher atmospheric temperature at that time.

(3) NP34-NP31 (85–77.5 cm): The quartz grains exhibit the textures caused by the most intense chemical solution-precipitation. There are not only the more oriented V-shaped pits, but also the only honeycomb etching surfaces and flaking texture with the highest present frequency in this core, which corresponds to the Holocene period with climate turning from cold to warm.

(4) NP29-NP14 (72.5–35 cm): The quartz grains exhibit a second high chemical solution-precipitation, especially NP14, show more etching pits and crevasses as well as more than 50% present frequency of SiO_2 crystals formed by a slow precipitation, in addition to more solution precipitation and amorphous precipitation, which reflects a warm environment.

The above mentioned paleoclimatic changes indicated by the assemblage features formed by chemical solution-precipitation nearly coincides with the views proposed by Luo *et al.* *

4 Conclusions

(1) The quartz grains of a core (NP95-1) collected from a continental slope at the Prydz Bay of Antarctica exhibit surface textural features caused by intense collision and compression of external stress and a weaker chemical solution-precipitation, indicating the sediments of the core were subjected to a marine glaciation and were under marine environment with low energy.

(2) The quantitatively statistical data for the assemblages of the surface textural features caused by chemical solution-precipitation are well correlated to the analytical results of micropaleontologic analysis and can better explain the cold-warm alternating changes of the paleoclimate in the sea area concerned.

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Plate 1

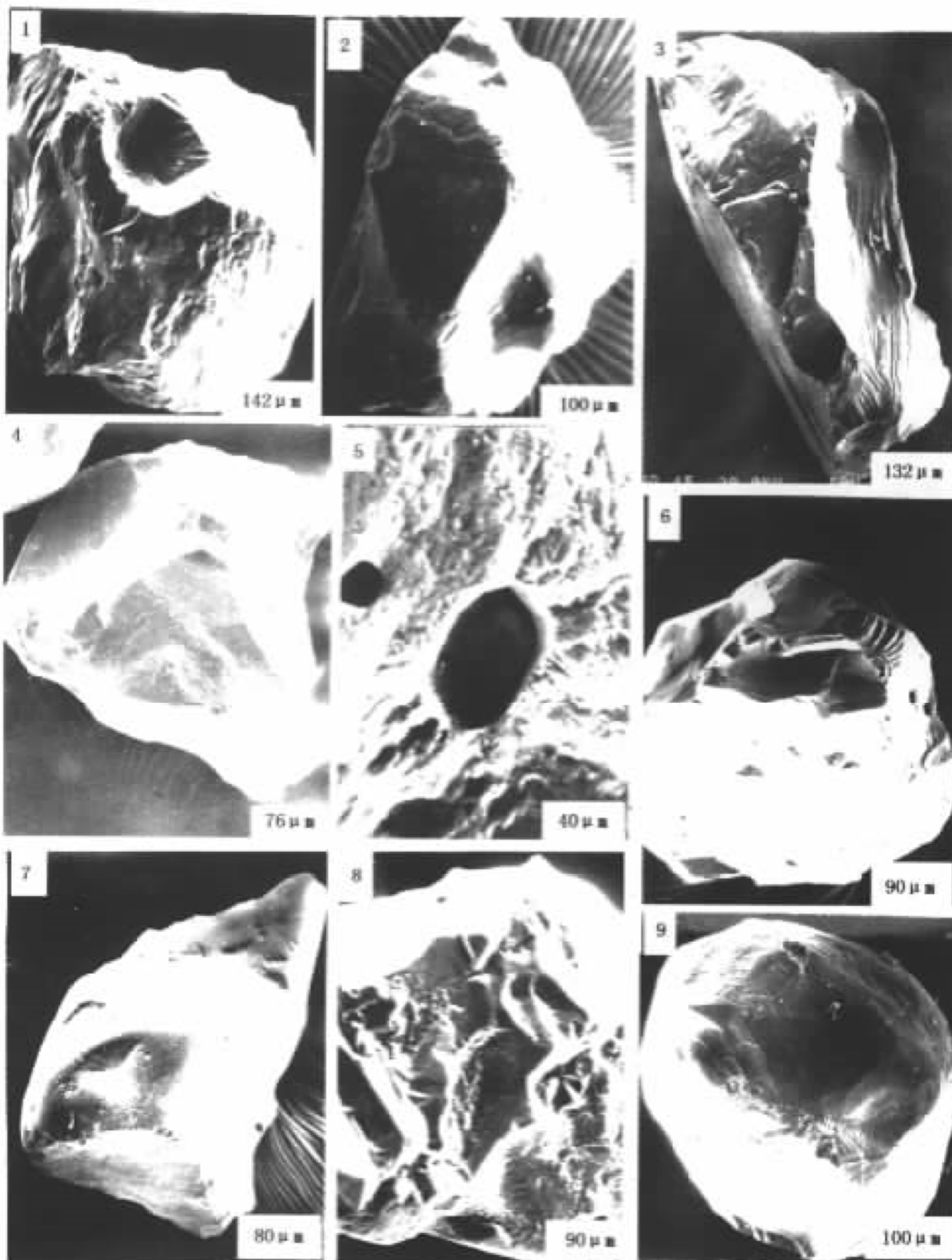


Plate II

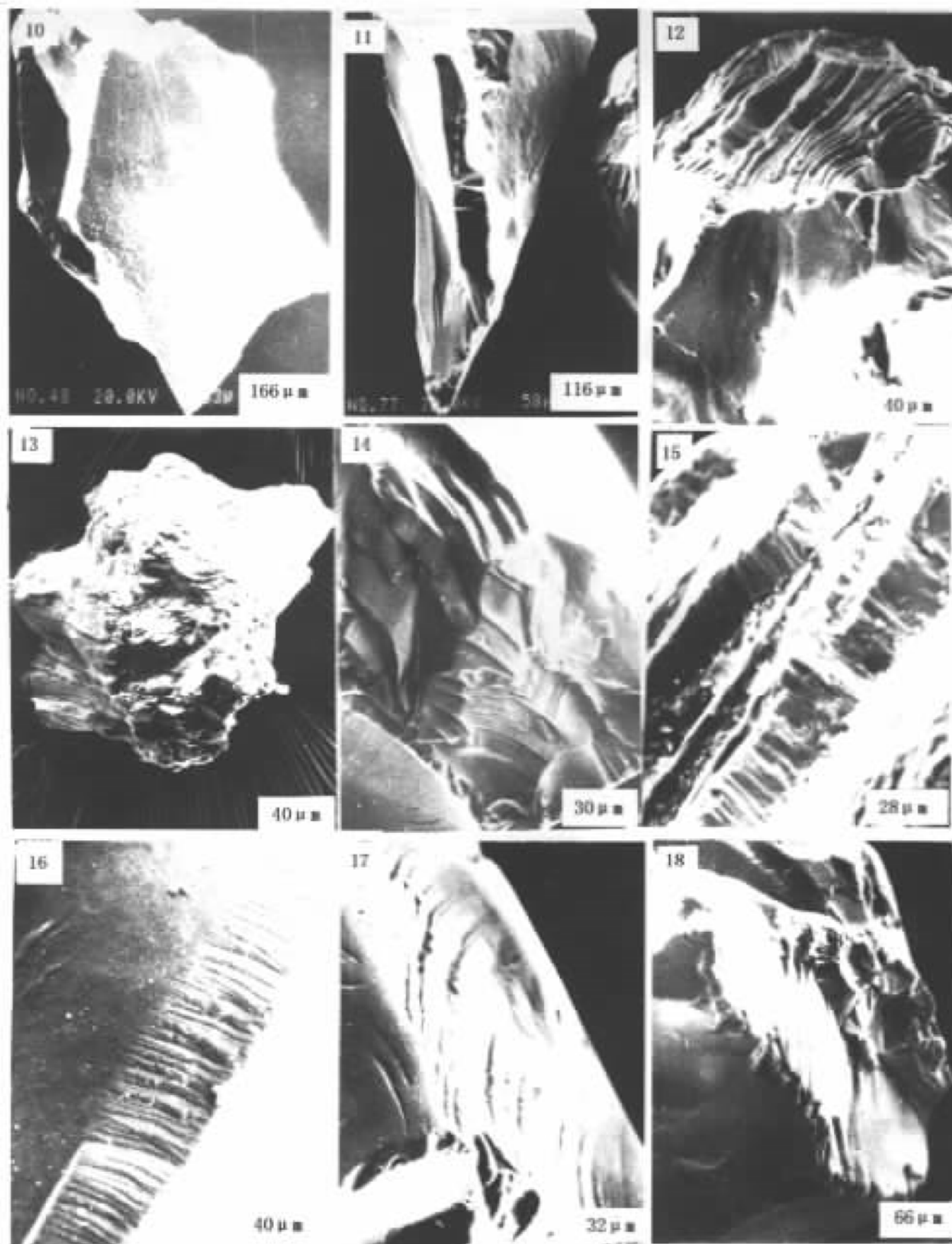


Plate III

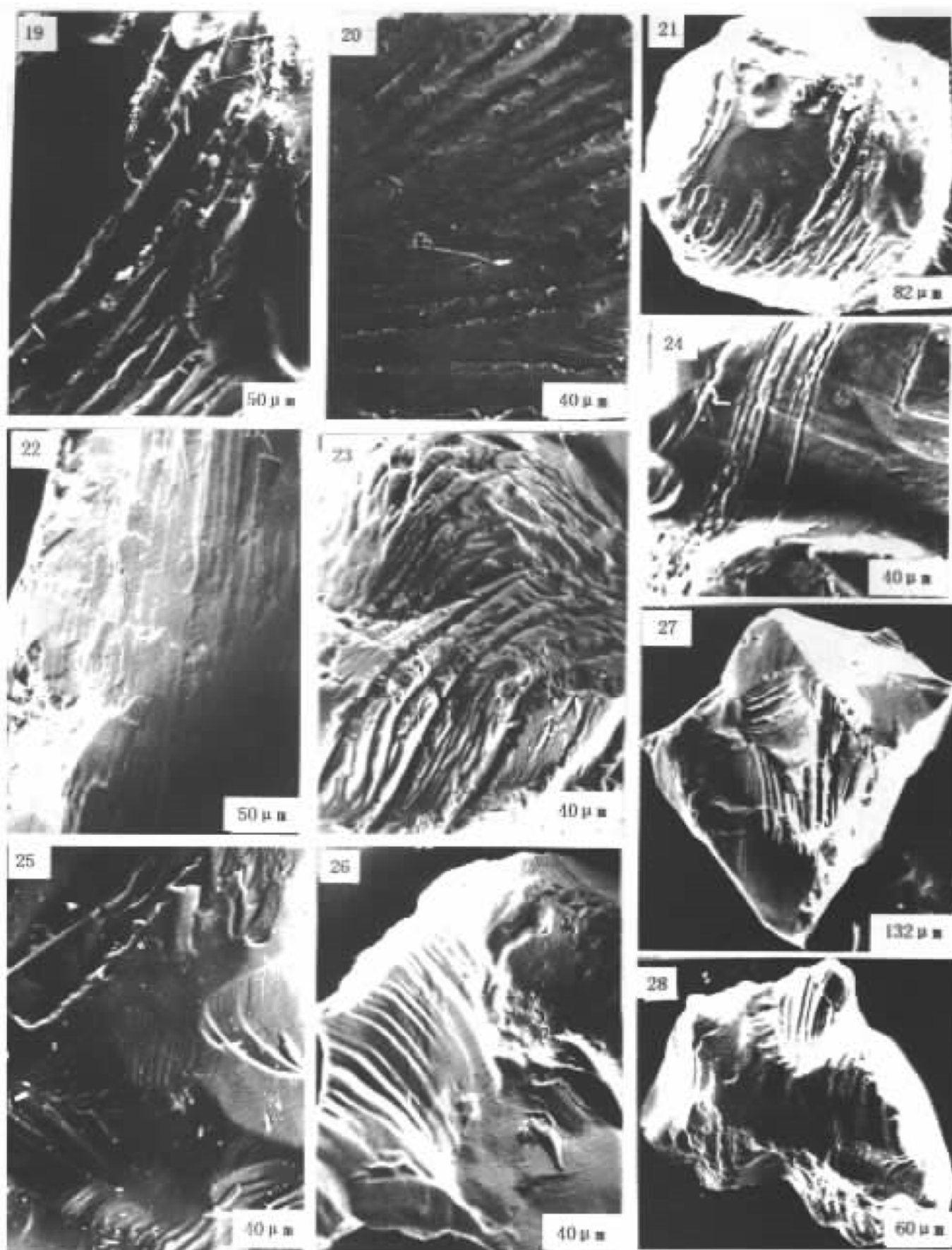


Plate IV

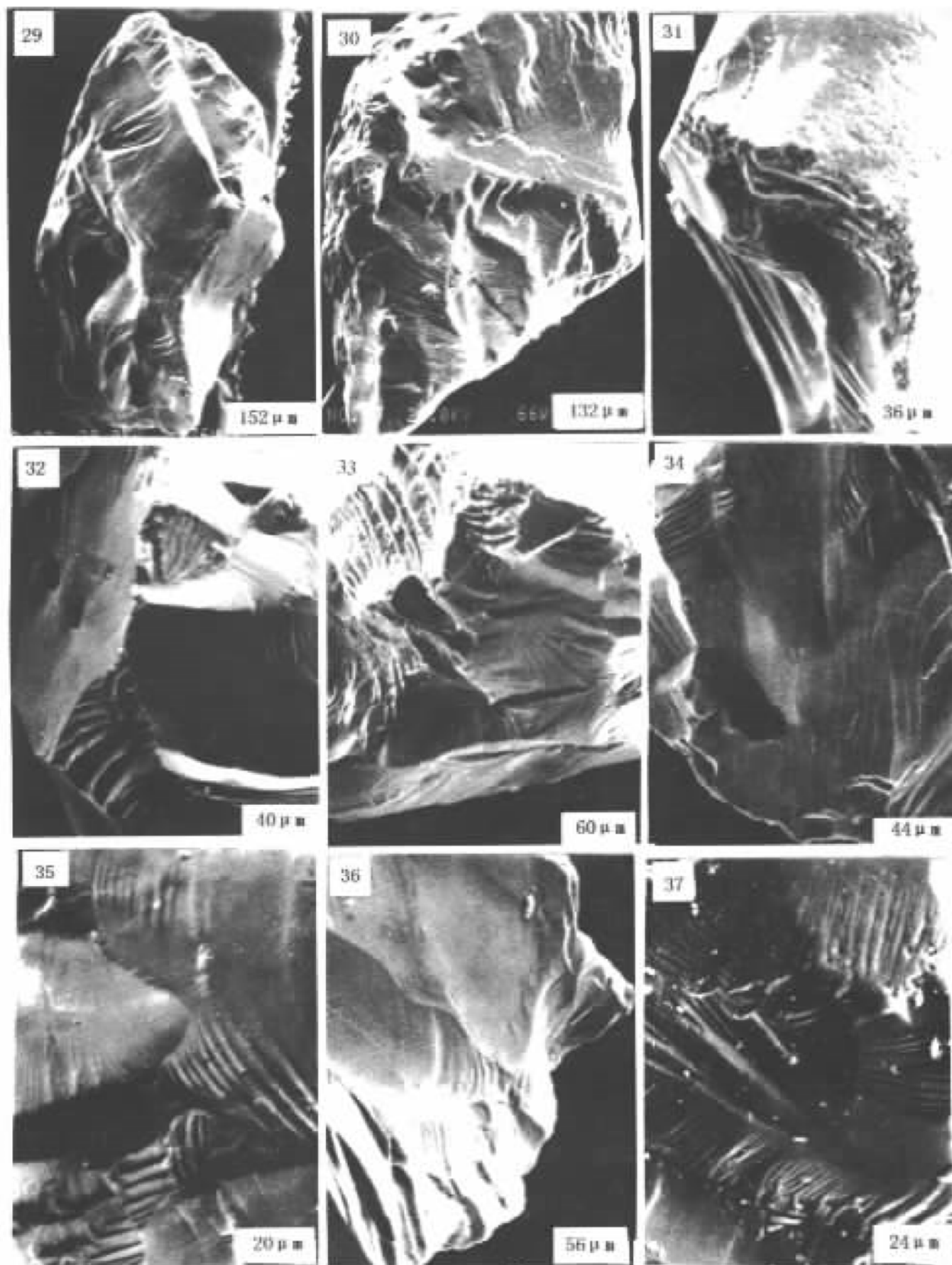


Plate V

