SOIL MICROMORPHOLOGY AND FAULTING

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INTRODUCTION

Soil characteristics are often used to indicate the minimum amount of time that has lapsed since last movement of faults (Douglas, 1973, 1974, 1975, 1980; Douglas et al., 1974; Machette, 1981; Page and Walsh, 1974; Riedmuller, 1972; and Woodward-Clyde Consultants, 1977, 1978). In these studies observed soil-fault interactions have included offset soil horizons, soil breccia, and soil microstructures associated with faulting. The presence of any of these pedological structures is thought to indicate fault movement postdating formation of the soil, and conversely the lack of these pedological structures is evidence that the last movement of the fault predates the soil. Modern theories of soil genesis (Cline, 1961; Novak et al., 1971) recognize that soil formation is an ever-continuing process. Such post faulting pedological development might mask the fault induced soil structures. If fault induced soil microstructures are to be utilized to indicate possible movement of a fault, such microstructures must first be cataloged. The objective of this study was to compare normal soils with faulted soils in order to identify the microstructures caused by faulting.

The study of microstructures in soil may be subdivided into micromorphometry, the study of soil pores, and micromorphology, the study of the solid fraction of the soil and the relation of the solid portion to voids. Both micromorphometry and micromorphology were included in this investigation.

Lafeber recognized (Barton, 1974) that in soils "...changes in applied stress would tend to lead to differential movement of grain, pore and matrix elements." Knoff and Ingerson (1938) suggested that objects in movement tend to have a significant preferred orientation in space. Thus it would seem that both the soil pores and the solid portion of the soil, in the zone of fault movement, should have preferred orientations (Ingles and Lafeber, 1966; Murphy et al., 1977) caused by movement of the fault.

METHODS

Undisturbed soil samples were collected in Kubiena boxes. In previous studies we have had difficulty collecting satisfactory samples from soils that lacked coherence, such as soil breccia zones. In this study in such cases, orientation lines were drawn on the sample, and then the sample carefully cut out with a hunting knife. Polyester resin was painted on the sample and a protective cover placed on the sample by building up the thickness of the polyester envelope. The samples were then transported to the laboratory. After air drying, the soils were vacuum impregnated (Altemuller, 1962; Fitzpatrick, 1980) with a polyester resin that included an ultra-violet fluorescent dye (9,10-diphenylanthracene). Polished blocks and large thin sections (2½ in. x 3 3/4 in.) were prepared for micromorphometric and micromorphological studies.

Data on soil pores was obtained by photographing the polished block under ultra-violet light. The resulting photograph showed soil pores (light colored) against a black background (soil matrix). Points representing ends of straight sections of soil pores were entered into a computer from these photographs using a stylus actuated digitizer.

Three-dimensional representations of pore orientations were obtained utilizing a major modification of Lafeber's (1965) techniques. Parallel serial sections were obtained by photographing a face of a polished block. About 150 μm was removed from the face, using a Lapmaster polishing machine, and a second photograph taken, etc. A computer program, based on the concepts of

Kalkani and von Frese (1979), was written which took the pore data from the serial sections and plotted numbers of pores by orientation on a steriographic projection.

Micromorphological data were obtained from thin sections and from polished blocks.

SITE DESCRIPTION

The site studied, in the gravel quarry[1] of the Kern Rock Company, near Mettlar, California, is shown in Plate 1 and Figure 1. Two faults were sampled. However, the northern fault, which splays, may be a splay off the southern fault. Three paleosols were observed. Paleosol I and Paleosol II have morphologies similar to Marchand's (1977) Modesto and Riverbank soils. Paleosol III is not as highly developed as Paleosol I. A holocene soil lies between Paleosol I and Paleosol III.

The samples collected for micromorphological studies are described in Table 1.

Displacement directions of the faults were determined from the relative displacements of Paleosol II and the loess which immediately overlies this soil and the nature of the drag zones. The small scarp (about 30 cm. high) associated with the southernmost fault indicates that the last movement of this fault may have been in the reverse direction.

MICROMORPHOMETRY

Steriographic projections were prepared, utilizing equal area nets, representing pores of sample B (Paleosol II) and sample D (drag zone of

1. We are indebted to Thom Davis, Dept. of Geology, University of California at Santa Barbara for bringing this site to our attention.

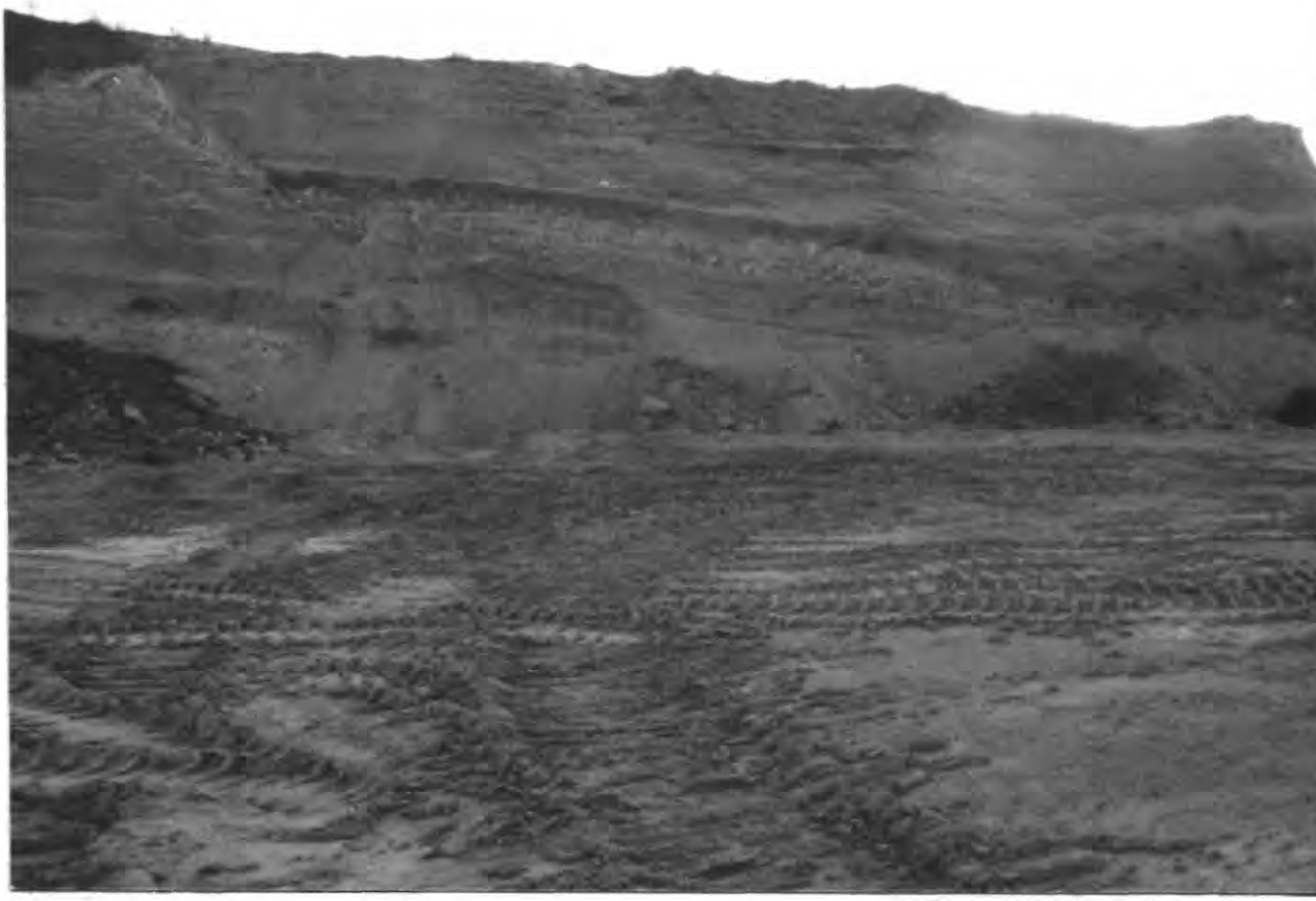

Plate 1. Faults and paleosols at the Kern Rock Co. quarry, Calif.

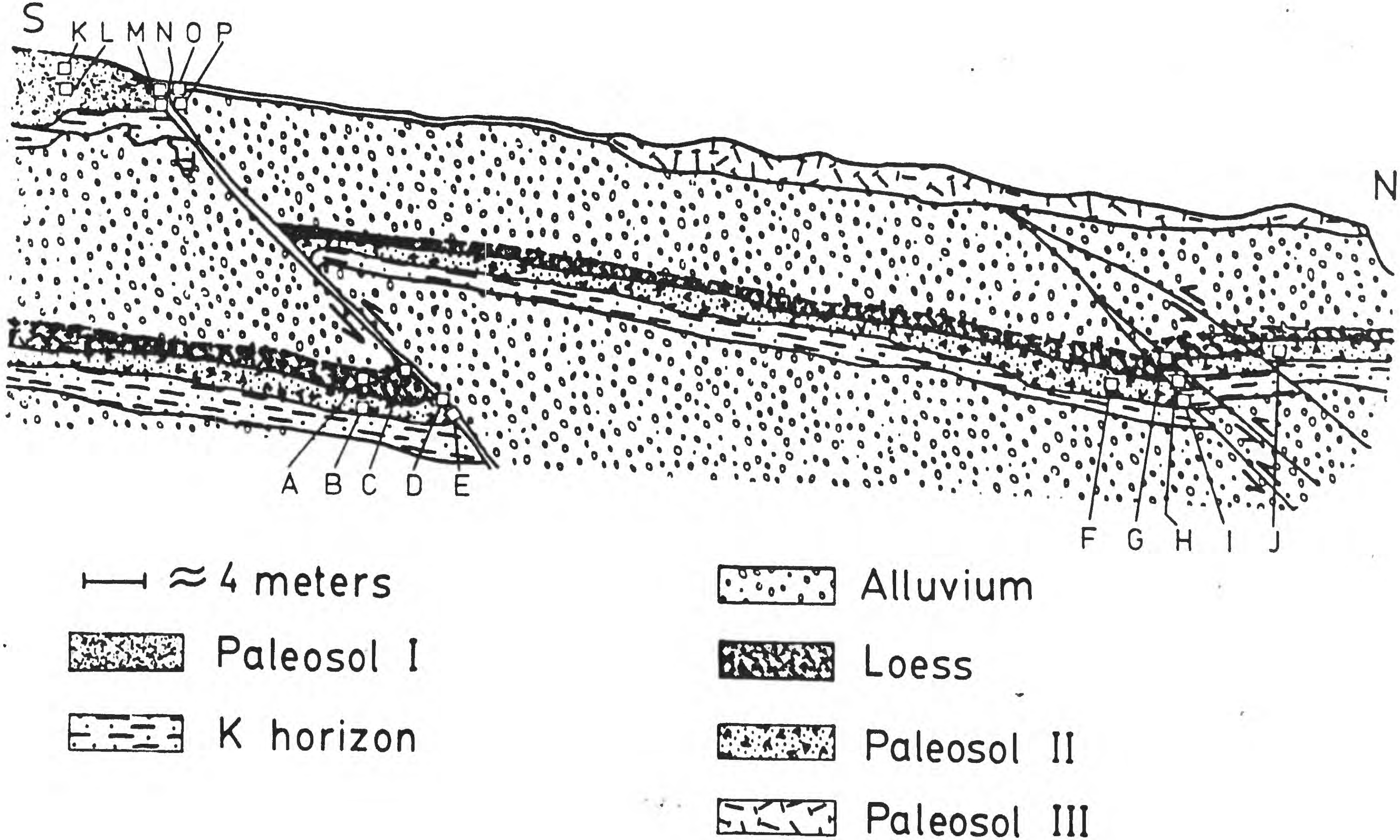

Figure 1. Faults and paleosols at the Kern Rock Co. quarry, Calif. (Letters indicate sampling locations.)

Table 1. Samples collected at the Kern Rock Company quarry. Sample locations are shown in Figure 1.

Sample	Description
A	Loess, 2 meters from fault.
B	Paleosol II, 2.5 meters from fault, 50 cm. above Paleosol, K horizon contact.
C	Across the contact of the fault and the drag zone of the loess.
D	Drag zone of Paleosol II, 15 cm. from the fault.
E	Paleosol II breccia, in the fault zone.
F	Paleosol II. 3 meters from fault.
G	Loess breccia, in the fault zone.
H	Paleosol II breccia, in the fault zone.
I	Drag zone of Paleosol II, 10 cm. from the fault.
J	Paleosol II, 25 cm. from the fault.
K	Paleosol I, 15 meters from fault, 10 cm. from soil surface.
L	Paleosol I, 15 meters from the fault, 75 cm. from soil surface.
M	Scarp zone of Paleosol I, 15 cm. from soil surface.
N	Scarp zone of Paleosol I, 75 cm. from soil surface.
O	Paleosol I, fault zone, 15 cm. from soil surface.
P	Paleosol I, fault zone, 75 cm. from soil surface.

Paleosol II) (Figure 2). The normal soil showed a moderate amount of orientation of soil pores while the drag zone showed a high degree of pore orientation with elongation in the direction of displacement within the drag zone.

MICROMORPHOLOGY

Factors that were compared in this investigation included: the pre-faulting soil micromorphology, the effect of the relation of the sampling site to the fault (near, far, drag-zone, etc.) on micromorphology, and postfaulting pedological development.

Paleosol I

Paleosol I was limited to that area south of the southernmost fault (Figure 1). The area of the fault zone was composed of mixed materials, including materials originating from Paleosol I and materials derived from the calcerous aluvium. Samples K, L, M, N, O and P were collected in pits, about 30 feet from the face shown in Plate 1. Sampling was limited to the A horizon and upper portion of the B horizon, and similar depths within the fault or scarp zone.

Voids in the B horizon of Paleosol I were principally irregular metavoids (Plate 2a). At a similar depth within the fault zone (samples N and P), there was considerable variation in void morphology, with irregular compound orthovoids (Plate 2b) being the most common type. Zones of assumed orientation, the orientation direction being parallel to the direction of movement of the fault, of silt and sand size particles (Plate 2c) were observed in samples N and P.

Paleosol II

Paleosol II had well developed pedological features (Plates 2d and 3a), with omnisepic fabric and void ferriargillans. Sample J, taken 25 cm. from the

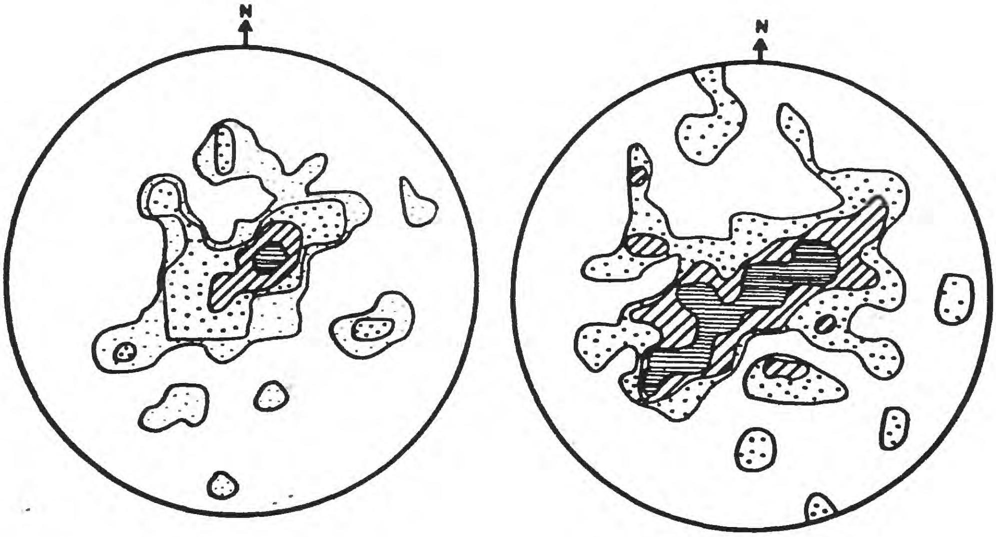

Figure 2. Equal area projections of densities of pores of similar orientation. Normal Paleosol II left (sample B) and drag zone of Paleosol II right (sample D).

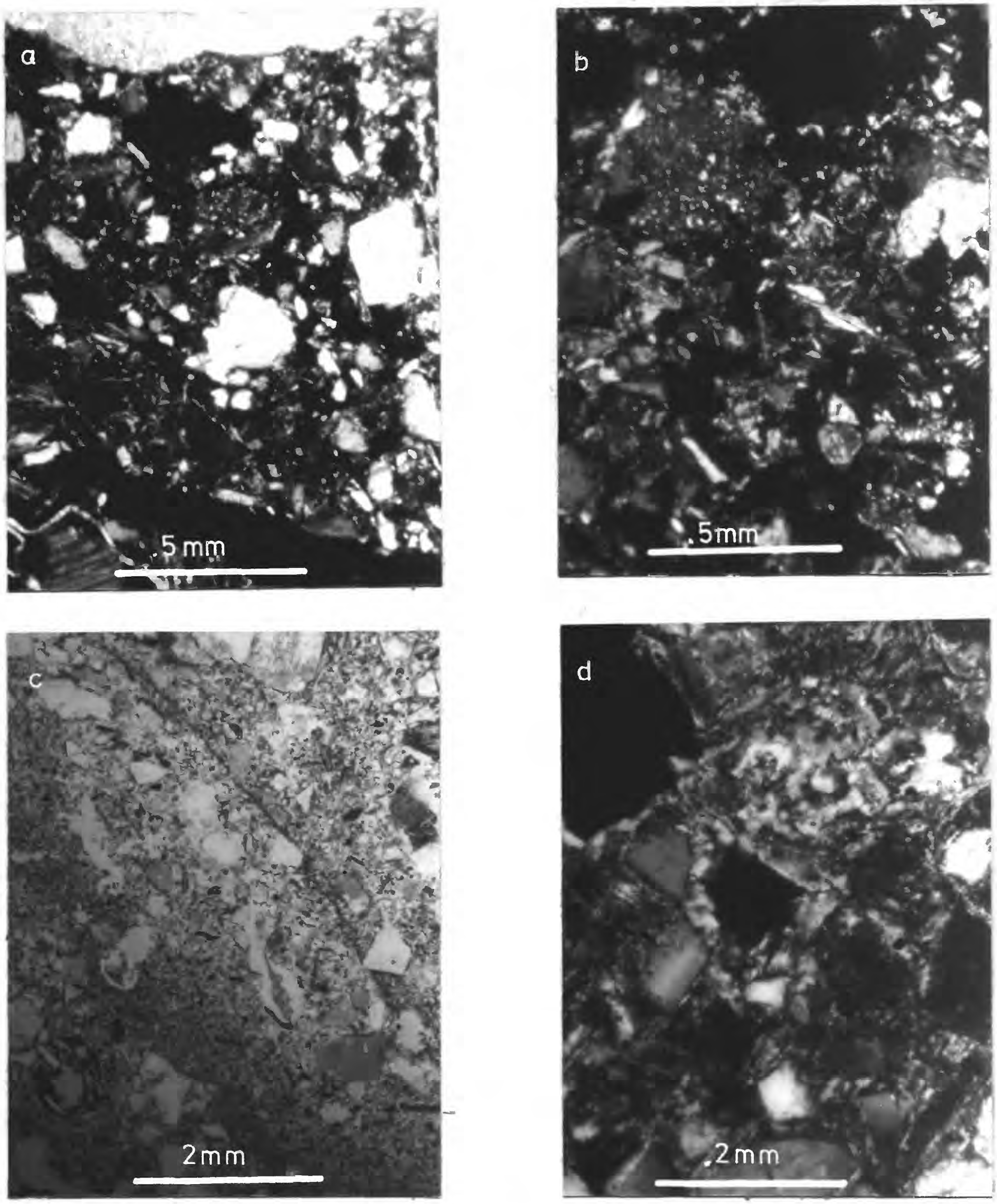

Plate 2. Paleosol I. (a) Soil fabric with metavoids (sample L). (b) Fault zone, apedal with orthovoids (sample N). (c) Fault zone, assumed orientation (sample N). (d) Paleosol II, fabric with metavoids and void argillans (sample B).

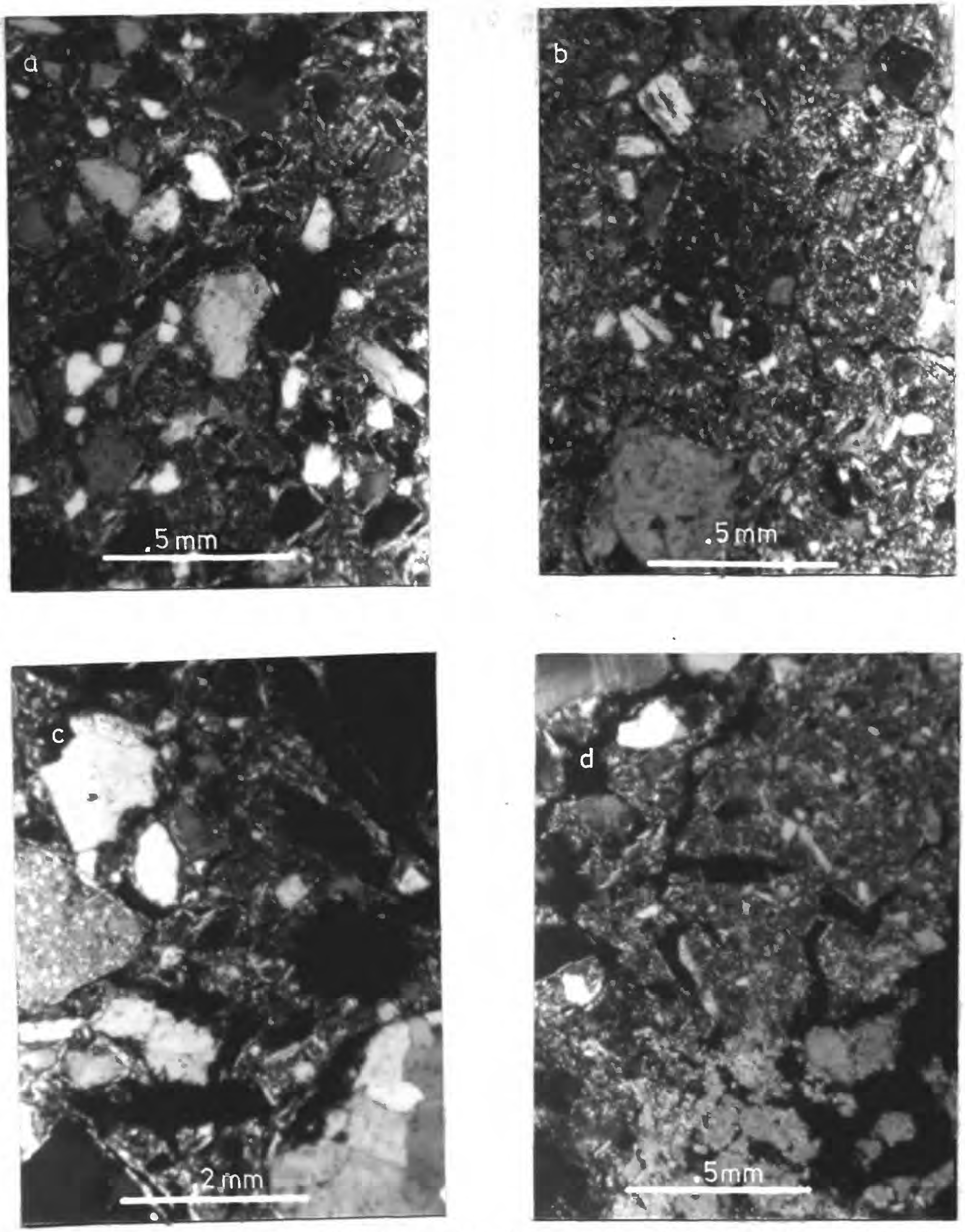

Plate 3. Paleosol II. (a) Soil fabric (sample F). (b) Thin channels without argillans, 25 cm. from fault (sample J). (c) Disturbed area within the drag zone (sample D). (d) Fault zone, recarbonation in pedorelect (sample I).

fault, had similar micromorphology to samples taken at considerable distance from the fault and also interconnecting channels that did not include argillans (Plate 3b). These channels were caused by movement of the fault. The drag zone had zones that could not be distinguished from the paleosol; however, many small zones had large populations of fault induced small orthovughs. (Plate 3c). The fault zone had an intricate pattern of crazy channels (Plate 3d). Although very small zones of s-matrix could be recognized within the fault zone the distribution of pedorelicts in the breccia could not be determined because extensive recarbonation obscured possible inherited fabric (Plate 3d).

Loess

The loess, overlying Paleosol II, did not include pedological features. However, many of the weatherable minerals showed considerable alteration and the development of intermineral pores. The loess had a single grain structure. Pores were limited to simple packing voids within interstices between mineral grains and intermineral pores.

Loess breccia had undergone extensive recarbonization. Downward moving water had dissolved carbonates in the overlying aluvium breccia. Some of these carbonates have precipitated in the loess breccia, often as channel neocutans or intercalary crystals.

Pores within the loess breccia included irregular orthovughs and ortho-skew planes.

Assumed orientation, of both sand and smaller size particles, was common within breccia zones (Plates 2c and 4a) with the strike being parallel to the direction of movement of the faults.

Classical fault-induced structures (Turner and Weiss, 1963) were numerous in breccia and drag zones (Plate 4b).

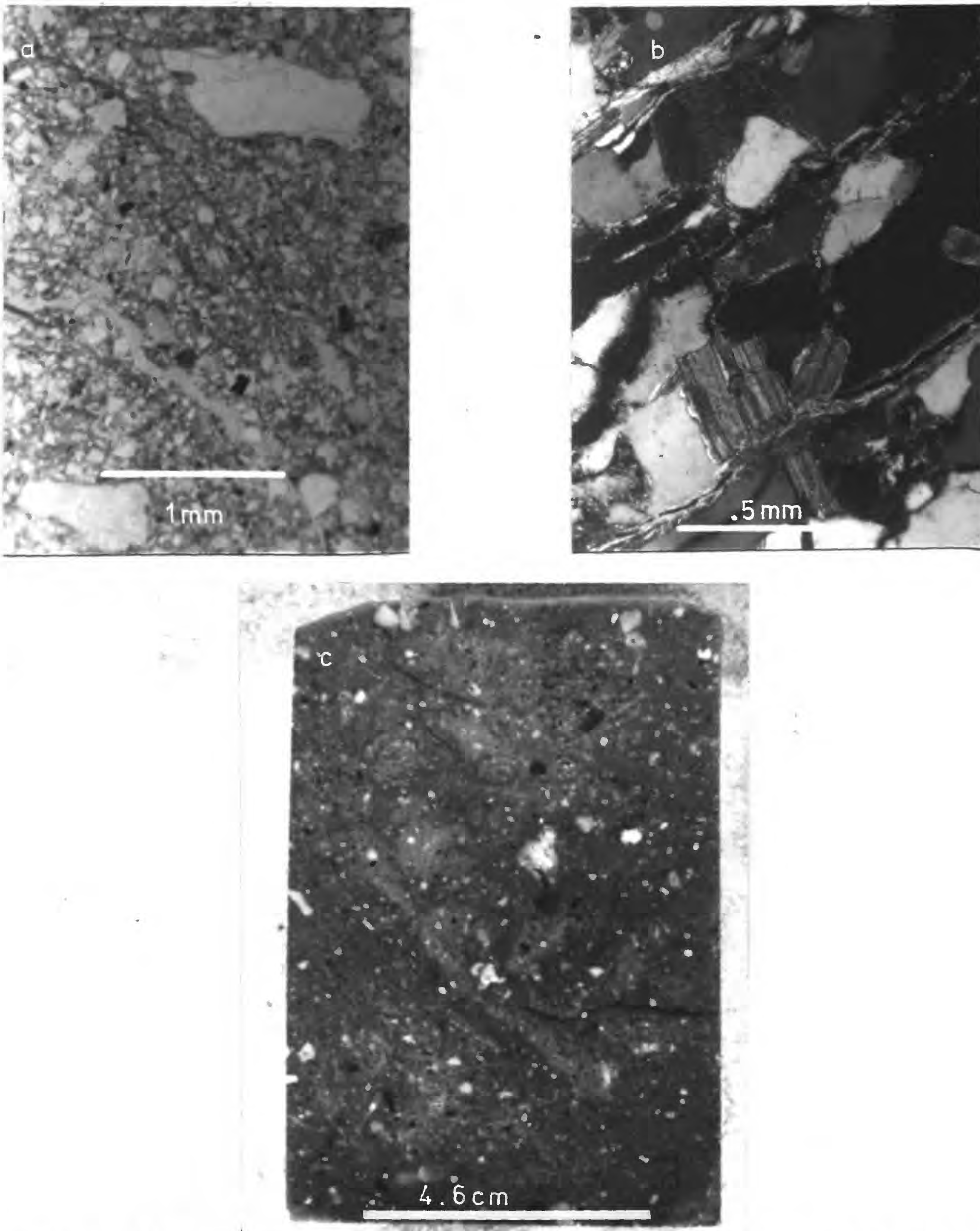

Plate 4. (a) Loess, fault zone, assumed orientation (sample G). (b) Paleosol II, fault sheared lithorelect with postfaulting argillans in shear zone (sample H). (c) Paleosol II, polished block. Fault runs from upper left to lower right. Lighter colored areas are zones of intensive recarbonation (sample H).

Post-Faulting Pedological Development

Sheared lithorelicts (Plate 4b) in the fault zone associated with Paleosol II sometimes had ferriargillans in their shear zones, indicating post-faulting pedological development. Similar, but thinner, ferriargillans were present on sand grains in the fault zone associated with Paleosol I.

Pedological recarbonation (Paleosol I) and geological recarbonation (Paleosol II) tended to mask any fabric inherited from the soil-fault interaction.

General Observations

When this study was initiated (1978), we were preparing thin sections 35 mm. x 45 mm. We judged these thin sections to be too small to use in order to adequately observe the variations in pedological features in a soil. We have modified our thin section machine so that we are now making thin sections 65 mm. x 95 mm. We consider these to be the smallest size sections that are practical for soil micromorphology studies.

Considerable information can be obtained from polished blocks (Plate 4c). Most often this information was utilized to direct attention to specific areas in the thin section.

In the earlier portions of this study, we had great difficulty obtaining samples from apedal zones. We found that if we took a large, random-sized sample (instead of trying to take a sample in a Kubiena box) and then painted the sample with resins from a standard "fiberglass boat repair kit," satisfactory samples could be obtained.

The lowest magnification obtainable on most petrographic microscopes is usually limited by the 4X objective of the microscope. We have obtained 1X and 2X objectives for our microscope. These are essential for studies of preferred (assumed) orientations.

CONCLUSIONS

Soil breccia zones have a unique micromorphometry and micromorphology. These zones are usually apedal, voids are ortho, and void argillans are absent. Assumed orientations are common with principal directions related to the direction of movement of the fault. Postfaulting pedological development may obscure fault induced characteristics. Care must be used when studying potential soil breccias because pedorelicts may be numerous; consequently, large thin sections must be used.

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Papers presented:

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Manuscripts prepared:

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Low, Alison J., Lowell A. Douglas and David W. Platt. Soil pore orientation and faults. To be submitted to: Proceedings of the Soil Science Society of America.