Appendix H:

CERAMIC THIN SECTION ANALYSES

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Blackbird Creek, Delaware

A Petrographic Analysis of Three Thin Sections

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In this report I describe the results of the petrographic analysis of three thin sections from New Castle County, Delaware. Two of these thin sections [NNN-1 and NNN-2] were prepared from pottery vessels recovered at the Blackbird Creek site [7NC-J-195D], while the third [KCN-36] was prepared from a sediment sample collected at a depth of 2.0 meters from a terrace of a nearby tributary.

Methodology

The three thin sections were analyzed using a point-counting procedure described in several earlier publications (Stoltman 1989, 1991, 2001). In this procedure, each thin section is placed on the microscope stage in a special attachment that is moved across the stage at specified intervals—1 mm in this case—beneath an eyepiece equipped with a crosshair and micrometer. At each stop (i.e., every 1 mm across the entire thin section), the point directly under the crosshair is assigned to one of the following classes: matrix, silt, sand, temper (if present), and void. For each of the sand and temper grains, the mineralogical composition is recorded and their sizes tabulated within an ordinal scale that is discussed below. In essence this is a sampling procedure analogous to overlaying each thin section with a 1 mm grid and recording the thin-section contents at every intersection point on the grid. This approach, referred to as modal analysis in the geological literature, has been proven to provide reliable estimates of the mineralogical composition of thin-sectioned samples (e.g. Chayes 1956; Galehouse 1971). In this study, the total number of points counted per thin section (exclusive of voids) ranged between 238 and 303. It has been my experience over the past 20 years that counting a minimum of 100 points per ceramic thin section produces reasonably reliable results and that counting more than 200 points consistently yields redundancy. The output of this approach is a physical characterization of each thin section in terms of the percentages of silt-size inclusions plus the species, sizes, and percentages of mineral inclusions of sand size and larger. Since specific clay minerals cannot be discriminated in thin section, their presence is recorded simply as “matrix”.

Two parameters, “paste” and “body”, are used to characterize the compositions of each of the thin sections (See Stoltman 1991:109-110; 2001:314). **Paste** consists of the naturally occurring minerals (i.e., exclusive of human additives) in each thin section. It is represented quantitatively as the percentages of three natural ingredients: (1) matrix (i.e., clay); (2) silt (all mineral inclusions that range in size between .002 mm and .0625 mm); and (3) sand (all mineral inclusions .0625 mm or larger in maximum diameter). A size index is also recorded for the naturally occurring sand and gravel grains in each thin section. This index is presented as an ordinal scale ranging in value from 1 to 5. It was computed for each thin section by assigning a value to all natural, sand-sized and larger grains recorded during point counting based upon maximum diameters as follows: **1**=.0625-.249 mm; **2**=.25-.499 mm; **3**=.50-.99 mm; **4**=1.00-1.99 mm; **5**=2.00+ mm. The index itself is a single number between 1 and 5 for each thin section that is the mean of all measured sand and gravel-size grains. The paste index is presumed to serve as a reasonable representation of the raw, clayey sediment used in the manufacture of a pottery vessel. The index used to characterize the sediment sample is, of course, paste.

In contrast to paste, **body** represents an artificial mixture of at least two materials—paste + temper—that typically derive from different geological sources. The discrimination of body from paste depends first and foremost upon the reliable identification of intentional, humanly introduced inclusions, i.e. temper. For the two pottery vessels in this study, metamorphic rocks were employed as temper. The identification of these inclusions as temper was relatively straightforward in this study, facilitated by their large size, high angularity, and distinctive polymineralic character in contrast to the natural sand inclusions. The **body** index is comprised of three components: (1) natural sand, (2) temper, and (3) matrix (silt is included here, along with the clay, as presumably natural ingredients). A separate size index, using the same 1-to-5 ordinal scale used to measure sand grains, is also recorded for temper.

Temper type, size, and amount are all variables that directly reflect human actions, thus are likely to be heavily culturally determined. Body indices, then, can provide a valuable basis independent of paste to assess the local vs. non-local status of ceramic vessels. An important caveat in dealing with temper as a culturally determined variable is to beware that it may not necessarily be a passive reflection of a traditional way of making pottery but a more active reflection of design considerations of the potters, who could be using different body recipes for vessels intended to perform different functions (e.g., ritual vs. cooking vs. storage vs. serving, etc.).

Sometimes it is possible to compare the findings of petrographic analysis with those of elemental analyses like neutron activation (NAA). In such cases it is important to realize that the latter applies only to body. That is, NAA results describe the *bulk composition* of ceramic samples, which is usually an artificial mixture of natural clayey sediments plus humanly introduced temper. In most cases (the exception is untempered pottery) NAA results cannot be expected to identify a clay source for ceramic products because of the complicating effects introduced by tempers. NAA findings for addressing the issues of ceramic production and exchange are thus most effectively employed through comparisons of ceramic samples with ceramic samples from presumed donor sites rather than with raw sediments. However, another complication enters here: diagenesis. It may be difficult, perhaps even impossible, to match the NAA chemical signature of a suspected exotic vessel with an external source because of the unknown (and unknowable!) effects that post-depositional alteration may have wrought on the vessel since it entered the archaeological context of a site far removed from its place of origin (See Stoltman and Mainfort 2002).

Characterizing the Three Thin Sections

The paste and body values for the two pottery vessels are presented in Table 1 along with paste values for sediment sample KCN-36. No body values are recorded for the latter since it is untempered, "raw" clay. I shall discuss each of the thin sections in turn then conclude with some summary remarks.

NNN-1/Sample 338-1

Assigned to the Marcey Creek ceramic series (properly so, I would say), this vessel is characterized by multiple grains of the rock, steatite, which can be regarded as temper without doubt. Steatite is an alteration product of olivine-rich rocks. It is composed primarily of the mineral talc, with lesser amounts of serpentine and apatite also present. In Plates 1 and 2 talc shows up prominently in the crossed-polar views because of its high, second and third order interference colors—the reds and greens. The uncolored mineral in Plate 1 is apatite. In Plate 2 the uncolored, laminated zone in the large steatite grain is serpentine, which may occur as separate grains, or, as in this image, in association with talc. The uncolored grain with the scale in Plate 2B is quartz. It is considered natural sand since quartz does not occur in steatite.

Table 1

Paste & Body Values for Each of the Three Thin Sections

PASTE

Type	Thin Section #	% Matrix	% Silt	% Sand	Sand Size Index
Marcey Creek	NNN-1	98	1	1	3.00
Dames Quarter	NNN-2	97	2	1	2.50
Mean & Std Dev	[n=2]	97.5±0.7	1.5±0.7	1.0±0	2.75±0.35
Sediment sample	KCN-36	94	4	2	2.40

BODY

Type	Thin Section #	% Matrix	% Sand	% Temper	Temper Type	Temper Size Index
Marcey Creek	NNN-1	78	1	21	Steatite	2.8
Dames Quarter	NNN-2	63	1	36	Diorite	3.25
Mean & Std Dev	[n=2]	70.5±10.6	1.0±0	28.5±10.6		3.02±0.32

From Table 1, it can be seen that the body of this vessel is comprised of 21% steatite by volume, with a mean temper size index of 2.8. This means that the average size of temper grains is in the coarse sand size range, i.e., .50-.99 mm. Other than temper, the composition of this vessel is noteworthy in its relative paucity of natural inclusions of both silt and sand. The principle sand inclusions are the mineral quartz that, interestingly, are sparse (only 1% of the paste) but generally coarse in size (sand size index for paste= 3.00, which is greater than the temper value). A coarse grain of quartz sand is shown in Plate 2.

NNN-2/Sample 409-2

This vessel has been assigned to the Dames Quarter ceramic series. It, too, is tempered with a metamorphic rock, but of a very different composition from NNN-1. As can be seen in Plate 3, the rock particles in this vessel are coarsely crystalline, i.e., derived from a plutonic igneous rock. They are composed principally of the mineral plagioclase, which has been subjected to considerable alteration as evidenced by the brown discoloration and presence of sericite (visible under crossed polars as fine, red, birefringent, micaceous inclusions on three of the larger plagioclase grains on the top half of the grain). In addition this rock contains lesser amounts of hornblende (the dark mineral with higher order interference colors at the bottom of the grain) and even lesser amounts of quartz (the small, clear, white grains seen best under crossed polars). Some plagioclase grains are twinned, showing both fine lamelli of Albite twinning and broader, twin halves of Carlsbad twins. All these factors together suggest that the temper used in this vessel derives from an intermediate igneous rock of dioritic composition that has been subjected to considerable post-depositional alteration. Depending upon the amount of quartz present, it is possible that quartz diorite may be a better designation for this rock (e.g., Le Maitre 1989).

From Table 1, it can be seen that vessel NNN-2 is more coarsely tempered than vessel NNN-1: its volume of temper is greater—36% vs. 21%—and its temper size is also larger—3.25 vs. 2.8. With a sample of but two vessels, it is currently impossible to make any valid inferences concerning the significance of these body differences. For example, the two vessels may reflect different pottery-making practices associated with two different cultural contexts or they might reflect different ceramic recipes associated with vessels engineered to perform different functions. Whether the two vessels come from different archaeological cultures or not, it is interesting to note the two vessels have virtually identical pastes (See Table 1) suggesting that they were made of the same, or closely similar (local?), clays.

Clay Sediment Sample KCN-36

The local clay sediment sample provided for my analysis was point-counted in exactly the same way as the two pottery vessels. To assess the relationships between the vessels and this clay sample properly, our comparative evaluations must focus upon the paste indices since no temper was added to KCN-36. There are some notable similarities between the clay and the vessel pastes. For example, sand grains are relatively sparse in all three (only 1-2% by volume), and those that do occur (mostly quartz) are relatively coarse in size (>2.40). However, KCN-36 is siltier than either of the vessels, with its 4% value falling outside of the two standard deviation range for the mean of the two vessels.

More importantly, however, is a qualitative distinction between the sediment sample and the two vessel pastes: the sediment sample seems to be composed of two distinct clays, a property not observed in the two vessel thin sections. This property is readily visible in Plate 4 under both crossed and plane polars. In the center of Plate 4 are two yellowish zones surrounded on all sides by a dark red field. The dark red of the latter is surely due to the oxidation of iron oxide, which seems to be lacking in the yellowish zones. Whether this apparent compositional distinction represents two distinct clays or zonal variation within a single clay is not known, but this sort of variation was not observed in either of the two vessel thin sections. Based upon the latter two considerations, I do not think that KNC-36 is a precise match for the pastes observed in the two vessels.

Concluding Observations

The two pottery vessels from the Blackbird Creek site thin sectioned for this report were observed to possess nearly identical low-silt, low-sand pastes, suggesting that they were made from the same, or closely similar, clayey sediments. While the one “raw” clay sample analyzed did not match closely the pastes of the two vessels, it is still reasonable to view both vessels as local products. Further support for this view could be marshaled if the tempers observed in the vessels can be confirmed as locally available. This requires relevant information concerning the local bedrock geology. Meanwhile, that two distinctly different tempers were observed in the two vessels—NNN-1 with steatite temper and NNN-2 with a plutonic rock of generally dioritic composition—leaves this issue of local manufacture unresolved. If the local availability of such rocks can be confirmed, the near identity of the pastes of the two vessels strongly argues that both were made from local resources regardless of whether or not their manufacture was coterminous.

Let me conclude with some observations concerning the obvious disparities that exist between the earlier petrographic analysis of these same thin sections and the present study. A significant problem, perhaps not appreciated during the earlier analysis, involves the fact that the thin sections lack glass cover slips. Important physical properties of minerals in thin section, including relief, birefringence, and twinning, are obscured or even masked when such uncovered thin sections are viewed with a standard petrographic microscope. Unless the thin section surface is covered by a liquid medium held in place by a glass cover slip, light reaching the thin sections' surfaces is scattered producing what can only be described as major optical interference for the analyst. Mineral identification in such thin sections is extraordinarily difficult. A temporary expedient that I learned from a geologist involves covering such thin sections with a thin film of water held in place by a glass cover slip long enough to allow completion of a reasonably comprehensive analysis. I frankly do not know what laws of physics are involved, but the visibility of the minerals is improved by an order of magnitude. I used this temporary, effective expedient to conduct my analysis. All the thin section photographs were taken under these conditions. In sum, I suggest that the disparities between the different petrographic analyses can be attributed to this state of affairs.

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List of Plates

[Each plate contains two views, A & B, of the same subject; A=view under crossed polars; B=view under plane polars;

All views taken at 10X magnification; for scale the maximum diameter of one grain is shown in part B of each plate]

Plate 1 Photomicrograph of Thin Section NNN-1, Marcy Creek Vessel

Steatite grain composed of polycrystalline talc + minor amounts of apatite

Plate 2 Photomicrograph of Thin Section NNN-1, Marcy Creek Vessel

Steatite grain composed of talc and serpentine; also present is a grain of quartz that serves as the scale

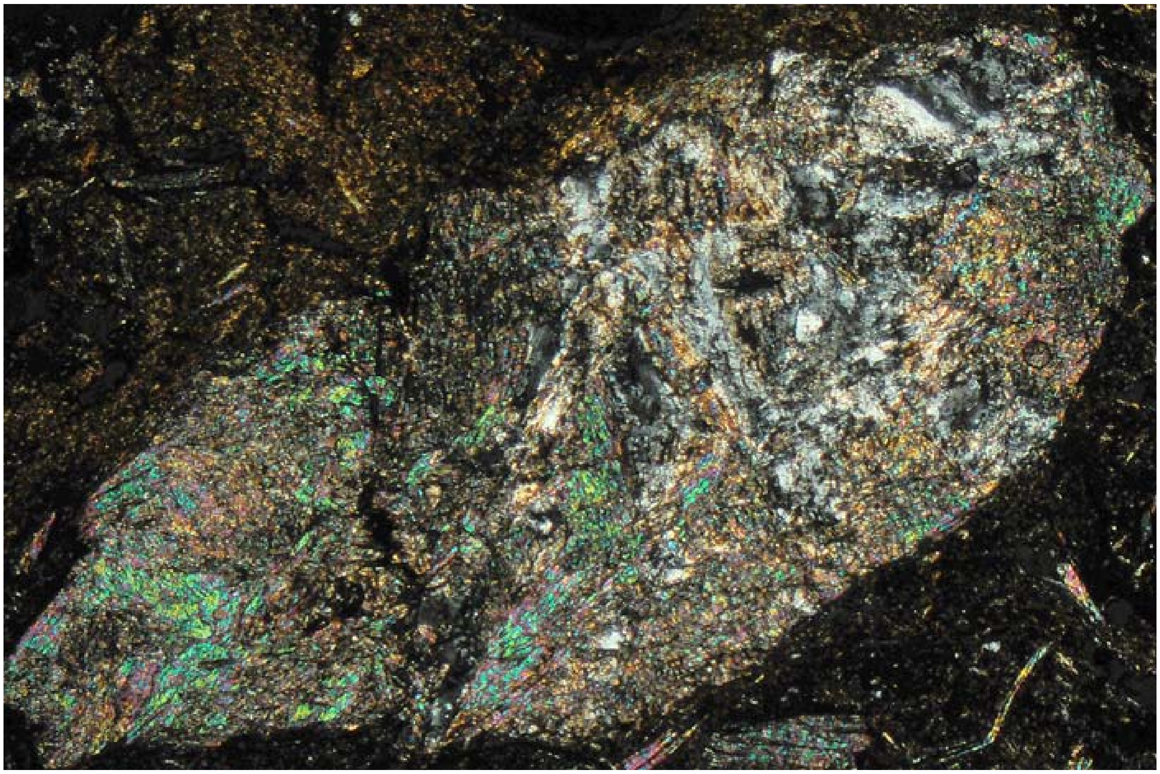
Plate 3 Photomicrograph of Thin Section NNN-2, Dames Quarter Vessel

Polymineralic grain of diorite (Quartz diorite?) composed mainly of plagioclase (which is altered and sericitized; both albite and Carlsbad twinning is visible in places) and hornblende + minor amounts of quartz

Plate 4 Photomicrograph of thin section of sediment sample KCN-36

Shows the intermixture what appear to be two different clays, one dark red and iron rich, the other (in the center) yellowish in color; two sand grains of quartz (uncolored) are visible in the upper part of the plate, one of which serves as the scale; the dark brown zone that occupies the center between two yellowish zones is due to vitrification of the clay

Note the relatively greater incidence of silt-size quartz particles in this thin section—these are the small, uncolored particles scattered throughout.



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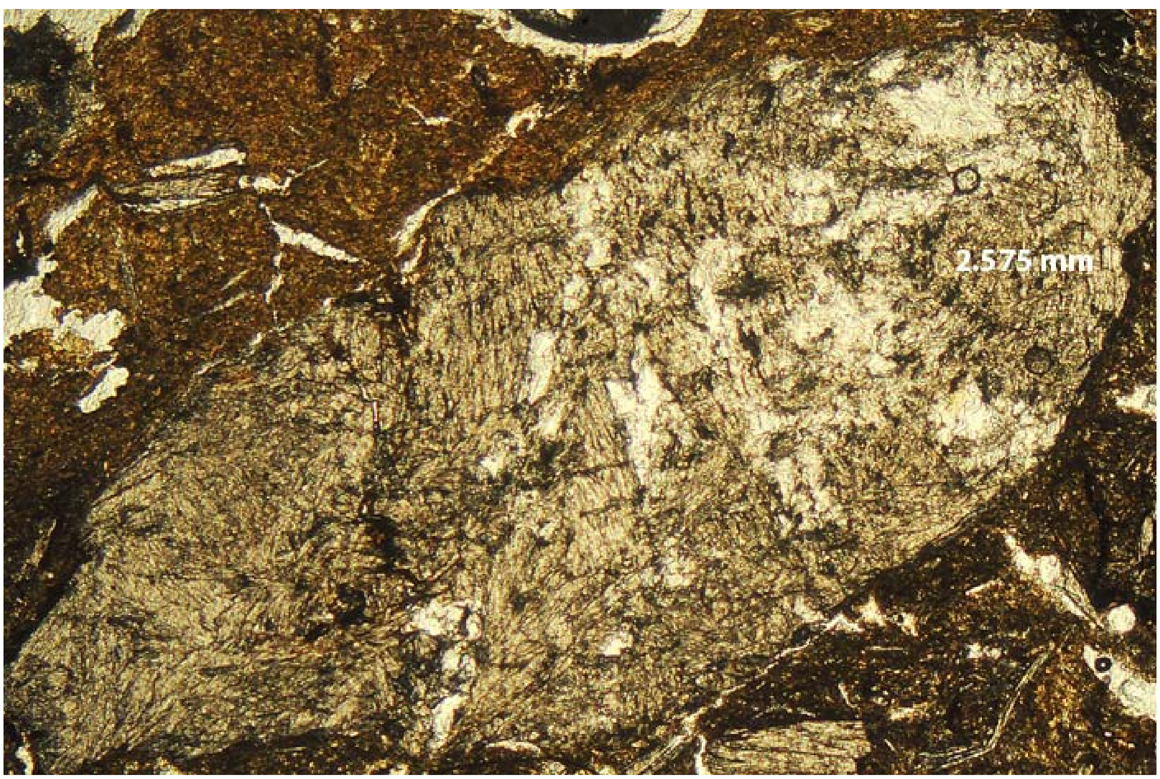

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Plate 1

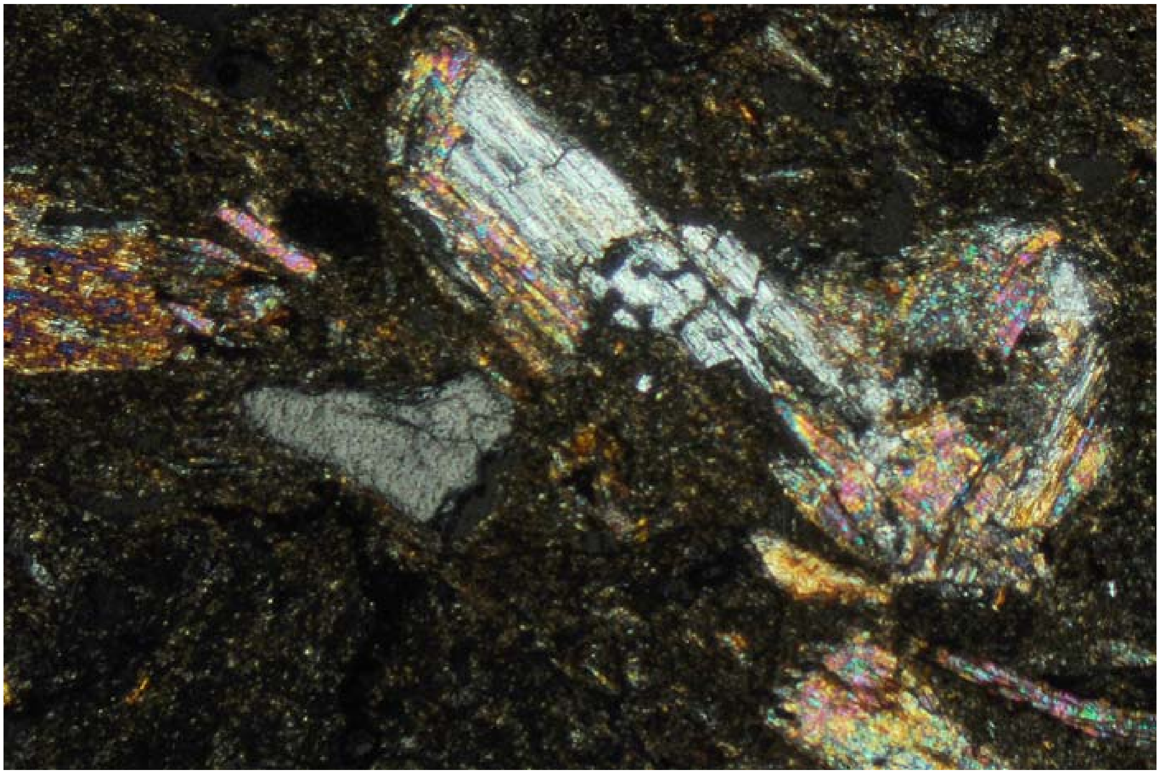

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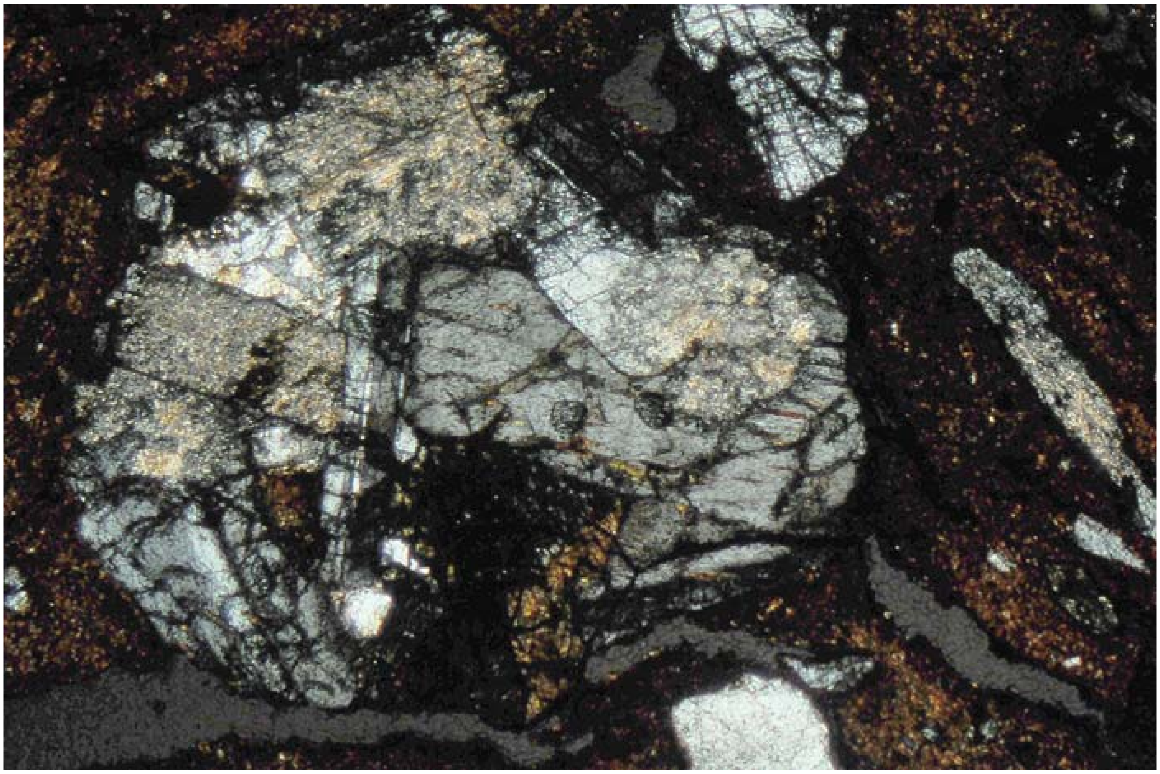
Plate 2



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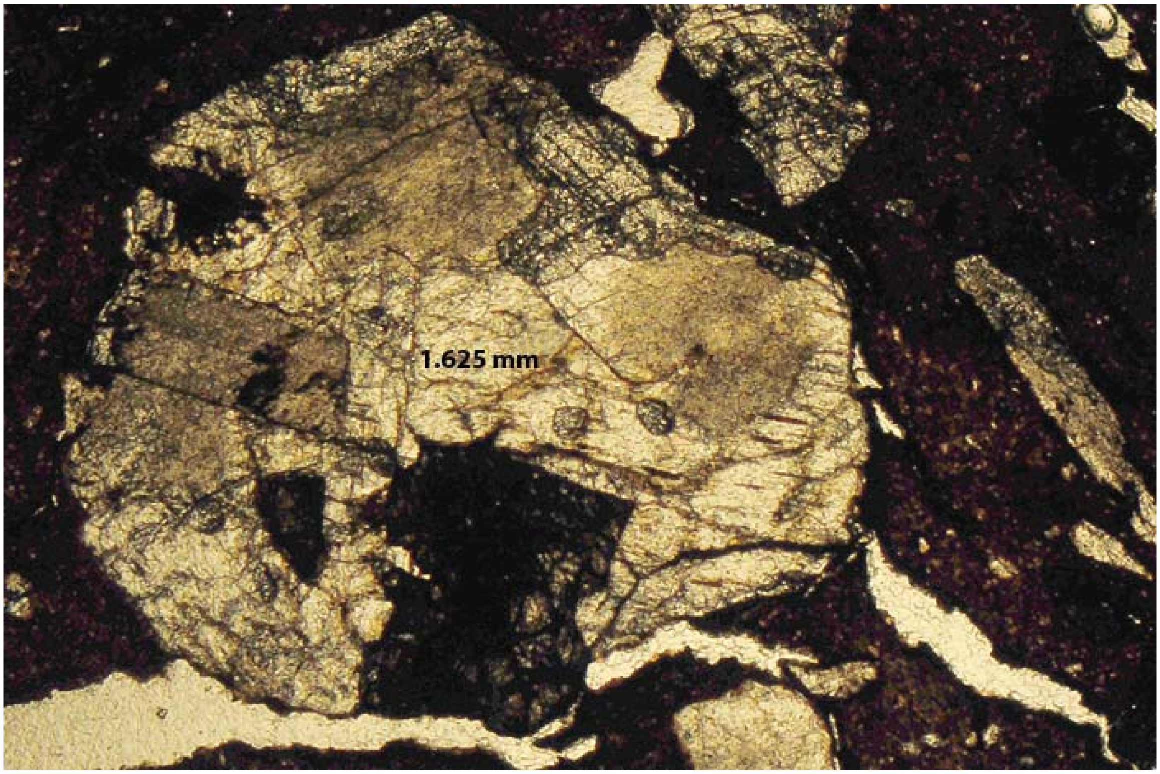

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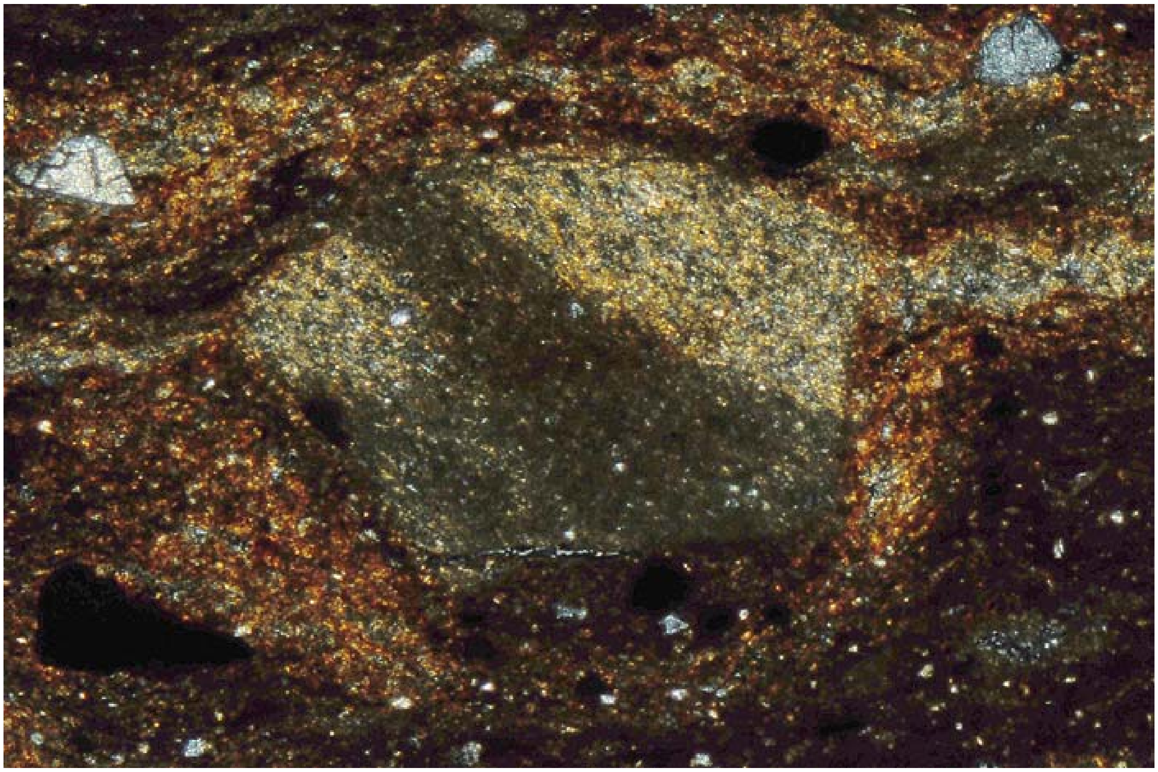
Plate 3



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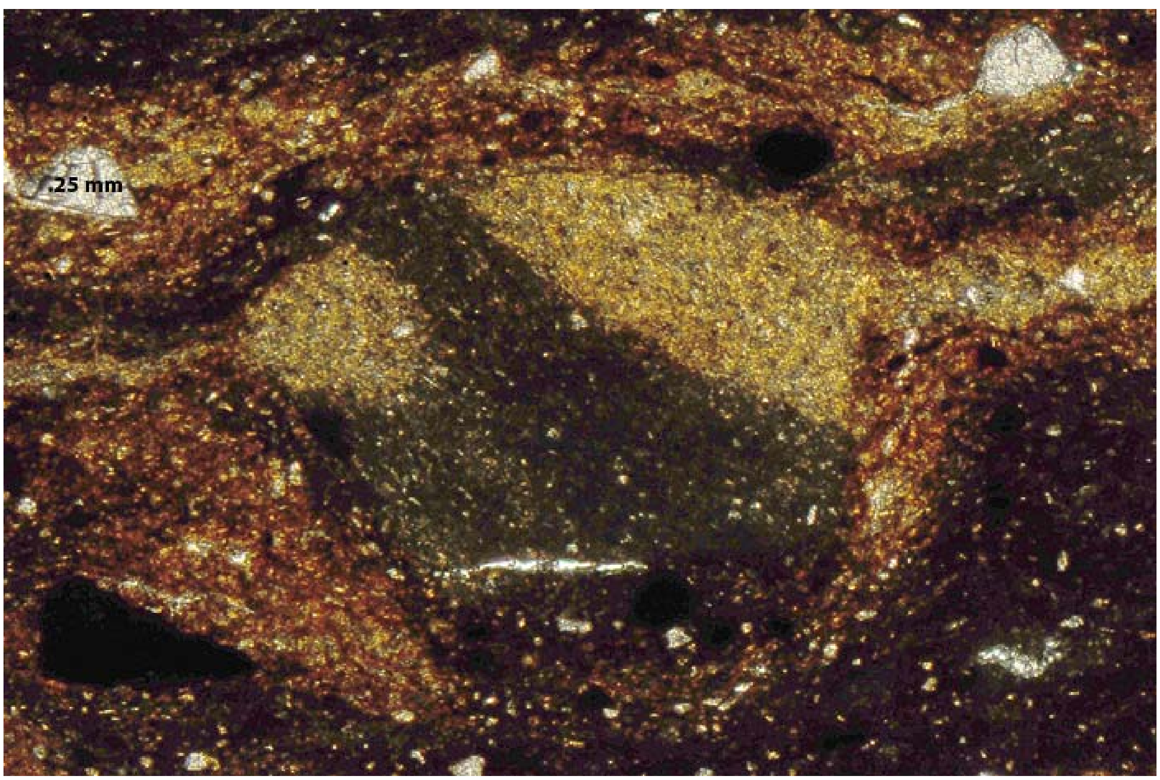

B.

Plate 4

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