Slide Tutorials

Up until this point, the main focus of the image atlas has been to provide guidelines for identification of individual silt- and clay-sized components in smear slides. The purpose of this tutorial section is to provide some detailed examples to aid in estimating percentages of components, as well as to hone skills in general component identification. Below are a series of images for several end-member examples of terrigenous and volcanogenic sediment types, all of which are included in the shipboard/repository smear-slide reference sets. Each tutorial example is first introduced with a written overview followed by several images/views at different magnifications and/or showing different areas of the slide. These have been annotated for identification of components and to illustrate the process of estimating percentages as described in Mazzullo and Graham (1988; http://www-odp.tamu.edu/publications/tnotes/digital/tnote_08.pdf).

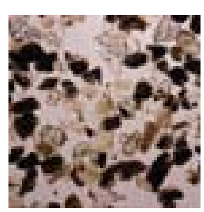
The first step in a smear-slide description is determining the texture of the sediment being observed, namely the proportions of clay-sized (≤4 µm), silt-sized (4- to 63-µm), and sand-sized (63- to 2,000-µm) material. The grain size is determined using a graduated scale eyepiece reticle that has been calibrated with an optical micrometer so that the 4-µm and 63-µm cutoffs for various magnifications, e.g., 10×, 20×, 40×, and 60×, are known. These grain-size estimates are most important for naming terrigenous (e.g., silty clay, sandy silty clay, etc.) and mixed sediments (Mazzullo and Graham (1988), as well as percentages of authigenic phases that may be used as modifiers, for example, zeolitic clay. Percentages can be estimated using comparator charts (e.g., Mazzullo and Graham, 1988).

Note that many of the silt/volcanogenic examples in this tutorial are made from the sieved mud (silt and clay) fractions of samples. Removing the sand fraction facilitates identification and percentage estimations of the silt and clay fractions. Coarser sand grains prop up the coverslip to a height that prevents focusing at high magnification on finer surrounding material. A similar effect to sieving can be created by segregating the coarser sand fraction in the sediment slurry to one end of the glass slide with the toothpick. In the finished product, this allows for focusing on fines in the "thin" end, yet maintains a sense of the proportion of coarser material on the "thick" end. Relative percentages have to be adjusted and should be coordinated with the core describers to avoid misnomers in sediments where there is a wide rage of grain sizes.

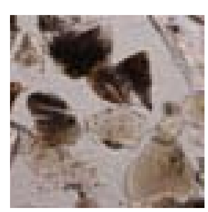
Volcanic tutorial 1a

Volcanic tutorial 1b

Volcanic tutorial 1c



Volcanic tutorial 2a



Volcanic tutorial 2b

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Silt tutorial 1a


Silt tutorial 1b


Silt tutorial 1c


Mud tutorial 1a

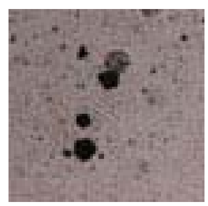

Mud tutorial 1b


Mud tutorial 1c


Clay tutorial 1a


Clay tutorial 1b


Clay tutorial 2a


Clay tutorial 2b


Clay tutorial 3a


Clay tutorial 3b

Volcanic Tutorial 1

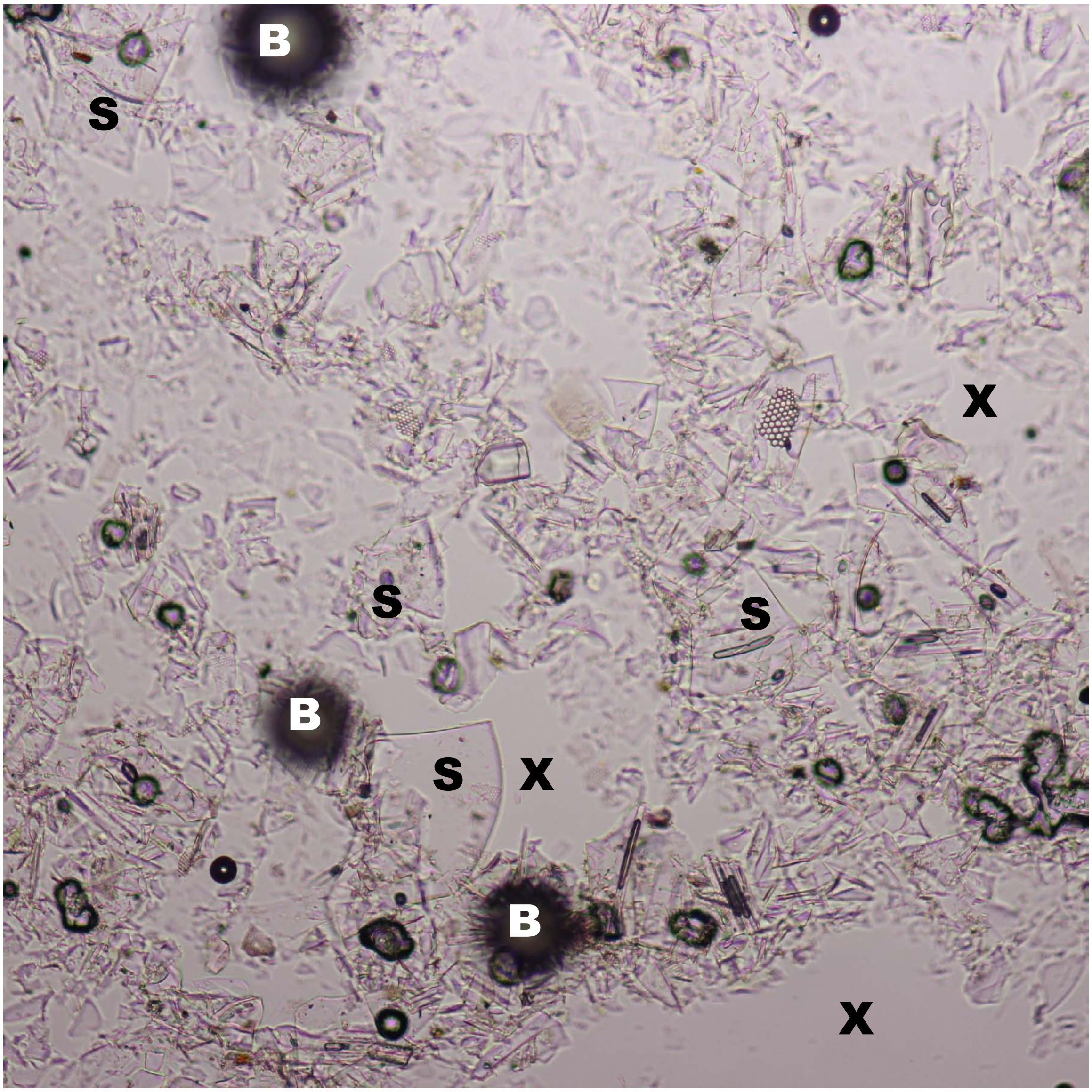
This is a sample of reworked pyroclastic debris from the Izu-Bonin intraoceanic arc. The components are essentially colorless (rhyodacitic) volcanic glass. The purpose of this tutorial example is to practice estimating the proportion of sand/silt and clay-sized material in the various fields of view. To help with this, in the lower-magnification images we have added a layer with a 63-µm scale where the 63-µm boxes approximate the sand/silt cutoff in each image set. We also add a layer in the higher-magnification images with boxes showing the dimensions of the silt/clay cutoff (4 µm). Image 1a shows a lower magnification view, whereas images 1b and 1c are at higher magnification. Note that when estimates are combined from the various fields of view, one could estimate the sand/silt/clay proportion to be roughly 5/85/10 classifying this as vitric silt (fine ash). The overall percentages of components: 5% clay size of indeterminate origin (glass, biogenic, minerals), 90% volcanic glass, with the remainder being biogenic (nannofossils, diatoms, organic) and mineral debris.

Volcanic tutorial 1a

Volcanic tutorial 1b

Volcanic tutorial 1c

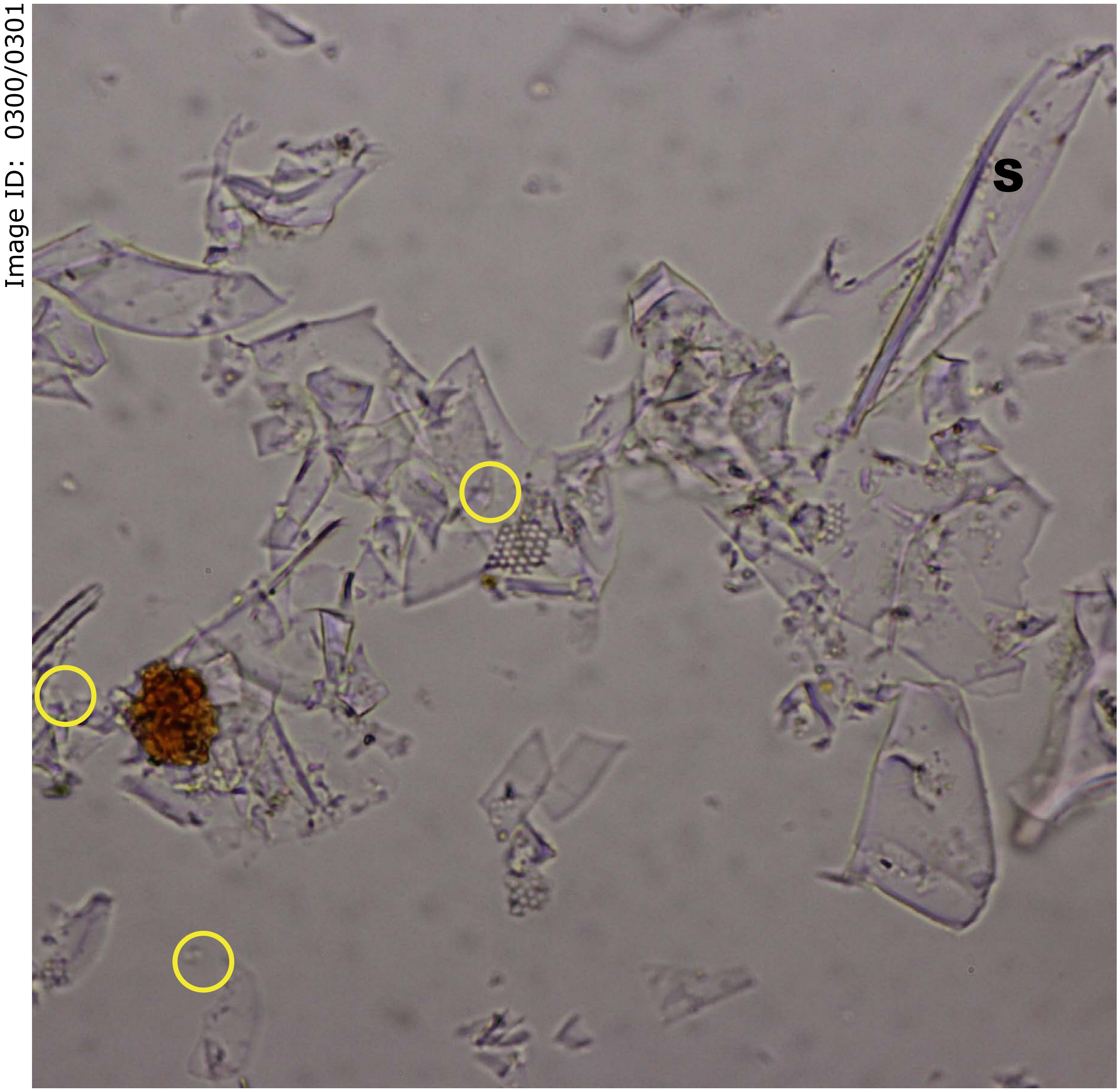
Image ID: 0298/0299



Volcanic tutorial 1a.

This is a general view of the slide at lower magnification showing dark bubbles in the mounting medium (blurry where larger). The 62.5-µm grid indicates that there are only a few potential, very-fine sand-sized grains in this field of view (~10% of sample). Most of the grains are silt-sized. This glass is isotropic, so when nicols are crossed, the non-glassy, birefringent components are emphasized, producing a "Milky Way" effect. Much of the birefringent material is in the fine silt- to clay-sized fraction. Glass fragments have a few identifiable, silt-sized plagioclase microlites. Roughly 10% of the field of view is bubbles (B) and 10% is sediment-free areas (larger ones marked with X), so estimates made of the sand (S) fraction, e.g., 10% of the field of view, need to be adjusted to ~13% (10% / 80% = 12.5%). All of the above are marked (B,X,S) in the information layer. The silt-to-clay ratio is better determined at higher magnification (see Volcanic tutorial images 1b and 1c).

IODP/ODP/DSDP Sample: Hole 791A, Core 34X, Section CC, 12 cm

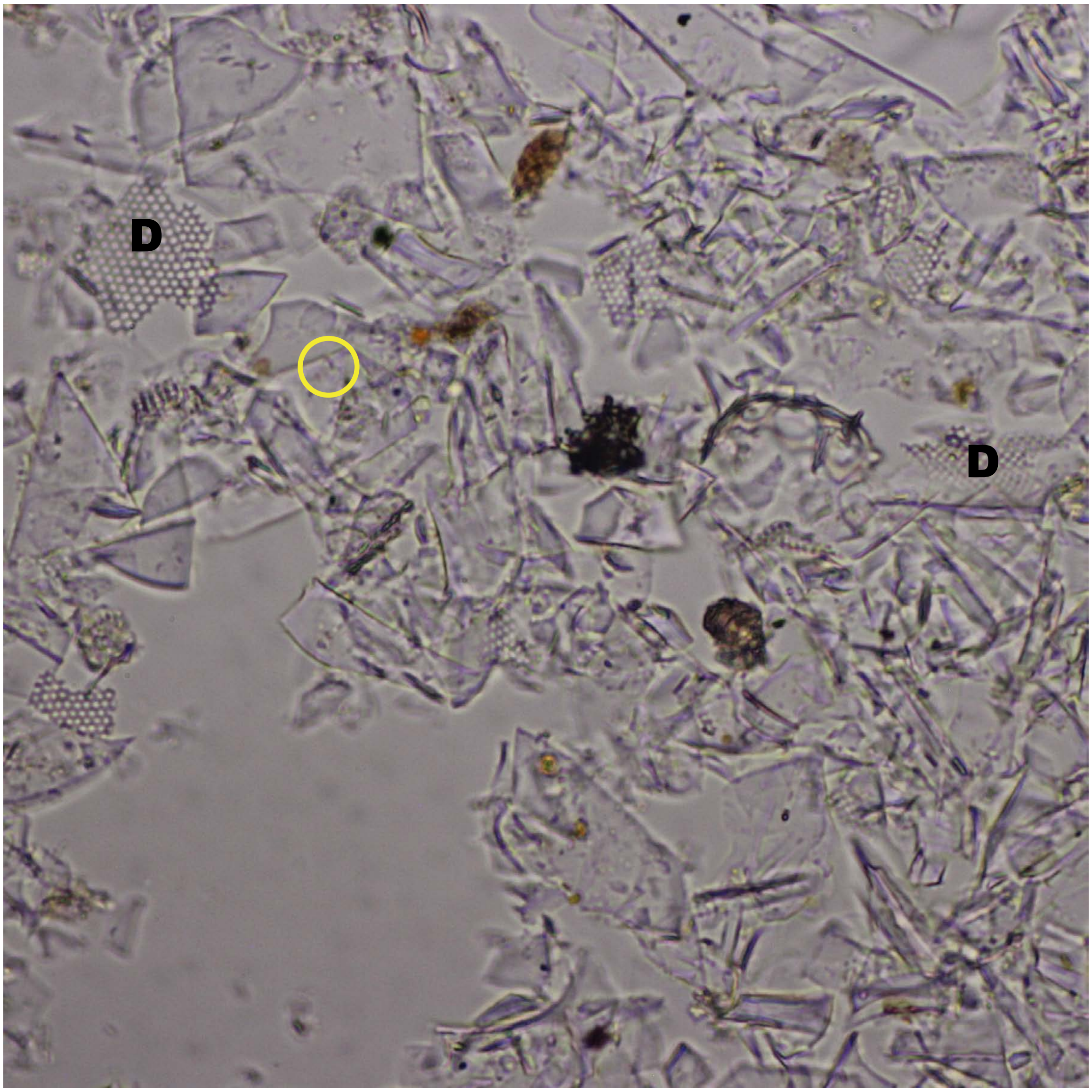


Volcanic tutorial 1b.

In this higher-magnification view, fine birefringent material can be discerned along with its tendency to adhere to the irregular surfaces of the glass shards. The distinct circular and segmented birefringent components are nannofossils (circled in yellow), which display first-order birefringence despite their calcareous composition owing to their fine grain size. There is only one elongate glass shard (S) with dimensions (length) that fall into the sand category. Note that this fragment would pass through a 63-µm sieve mesh and should be categorized as silt owing to its small median dimension. The silt to clay ratio can be estimated from this field of view after first estimating the percent component vs. space: a quick estimate of ~30% can be made by imagining all grains moved to fill the central part of the field of view. A more precise counting of components vs. space using 10-µm grid intersection points provides an estimate of 40% in this instance. This method also estimates that 2.5% of the field of view is clay-sized material, mostly birefringent; the percentage adjusts to ~6% of the sample once the overall percentage of material in the field of view is taken into account (2.5% / 40% = 6%). The origin of the circular orange grain in left center is indeterminate (organic? oxide? biotite?).

IODP/ODP/DSDP Sample: Hole 791A, Core 34X, Section CC, 12 cm

Image ID: 0302/0303



Volcanic tutorial 1c.

Unlike volcanic image 1b, the material in this field of view is more closely packed, filling approximately 20% of the field of view. Most of the open space is in the lower left part of the image and material is so densely packed in some areas (on right) that may cause overlap and affect percentage estimation. There are no sand-sized grains here, only silt (95%) and clay (vitric, mineral and biogenic). The silt fraction includes 2% silt-sized minerals, 2% silt-sized nannofossils (circled in yellow), and 4% broken fragments of diatoms -- isotropic opaline tests with a fine honeycomb texture (D). Note that there is also one fragment of this material in volcanic tutorial image 1b.

IODP/ODP/DSDP Sample: Hole 791A, Core 34X, Section CC, 12 cm

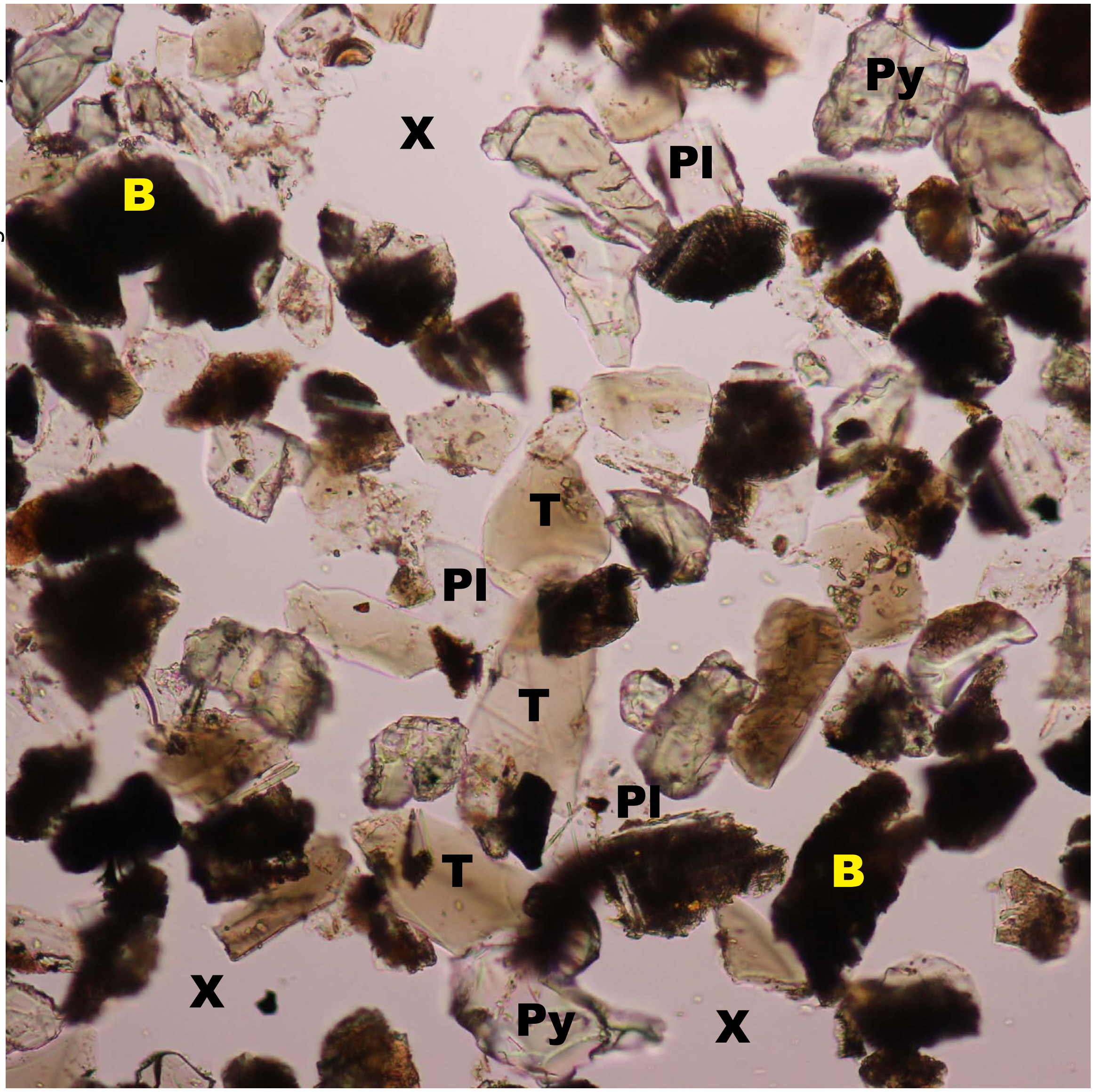
Volcanic Tutorial 2

This is a sample of reworked pyroclastic debris from the Izu-Bonin intra-oceanic arc. The components are mainly tan to black, intermediate to mafic volcanic glass, plagioclase, and dense mineral fragments. The sample has been sieved to remove the sand fraction. Apparent sand-sized grains are generally elongate with intermediate and smaller dimensions in the silt range, which allowed them to pass through the 0.0625-mm sieve mesh. This sample has only a trace of clay-sized material.

Volcanic tutorial 2a

Volcanic tutorial 2b

Image ID: 0308/0309

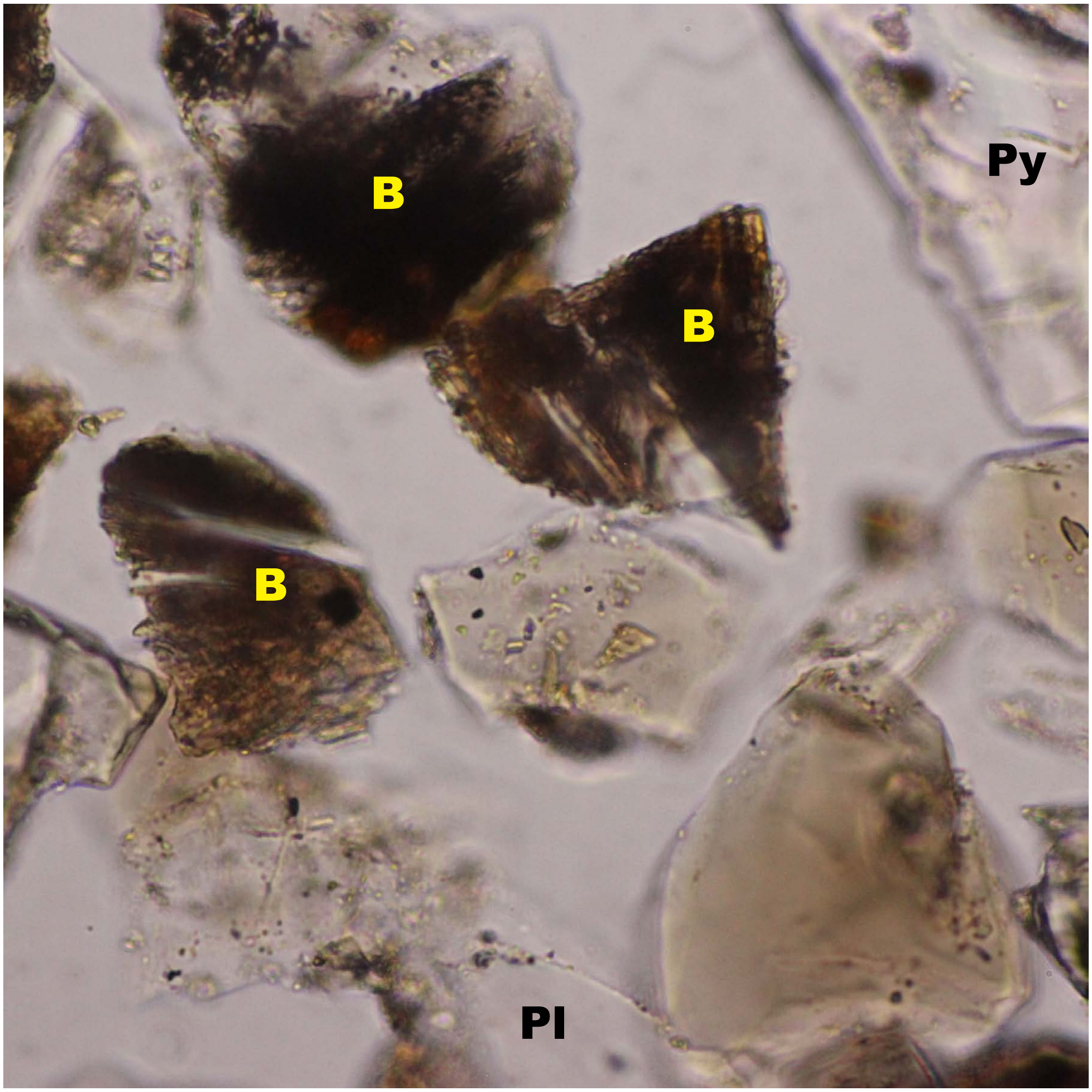


Volcanic tutorial 2a.

In plane light, the volcanic glass is tan (T) to brown to nearly black (B) in color and is isotropic, exhibiting no birefringence with nicols crossed. Several fragments contain plagioclase microlites (M). Pyroxene (and perhaps olivine?) crystals exhibit higher relief and birefringence (Py), the latter up to second-order colors, whereas the plagioclase (Pl) has lower birefringence and relief and locally exhibits twinning. Estimating component percentages requires examining the sample in plane light and with nicols crossed. Approximately 30% of the field of view is pore space (X); the remaining 70% comprises black glassy fragments (30%), tan to light brown glassy fragments (16%), plagioclase (16%), and pyroxene (and minor olivine?). The darker glass is still slightly translucent and locally contains microlites of plagioclase.

IODP/ODP/DSDP Sample: Hole 791B, Core 62R, Section 1, 3 cm

Image ID: 0310/0311



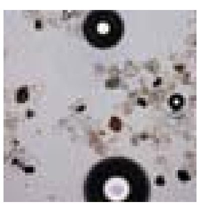
Volcanic tutorial 2b.

This high-magnification view shows the semitranslucent nature of the “black” glassy fragments with semialigned, elongate, colorless plagioclase microlites (M). Grains with low birefringence (first-order colors) are plagioclase (Pl) to pyroxene (Py). One large fragment of pyroxene exhibits higher birefringence.

IODP/ODP/DSDP Sample: Hole 791B, Core 62R, Section 1, 3 cm

Silt Tutorial 1

This is a sample of silt from the Amazon Fan in the central Atlantic Ocean. The components are essentially silt-sized detritus sourced from South America. The purpose of this tutorial example is to practice estimating the proportion of silt components, e.g., mineral grains and lithic fragments, at various magnifications. Percentages given are calibrated in the same way described in Volcanic tutorial 1, first estimating the percentage of the field of view filled with a component (either using comparison charts or grid counts) and then correcting it to reflect the percentage of the field of view filled with sediment. For example, a component estimated at 20% of the field of view, a view that in turn was only half filled (50%) by sediment, would constitute 40% of the sediment sample. In this example, the broad percentages of components are first estimated at lower magnification (1a) and then in several areas with more densely packed grains (1b and 1c). These results are combined to give an estimate of 15% dense minerals, 15% carbonate, 55% quartz (monocrystalline and polycrystalline) and feldspar, 15% lithic fragments, and a trace of biogenic debris, potentially recycled. The ratio of feldspar to quartz is harder to estimate, as high as 1:3 but likely lower. The sediment is very well sorted and classified as silt, mainly coarse to medium silt using the Udden-Wentworth scale. The large percentage of carbonate debris is suspected to be detrital carbonate lithic debris sourced from carbonate rocks. If the carbonate were authigenic, in situ cement, the grain (crystal) size and texture might be more uniform and the crystals more euhedral. One might also expect to see carbonate cement crystals partly adhering to the host silt sediment.

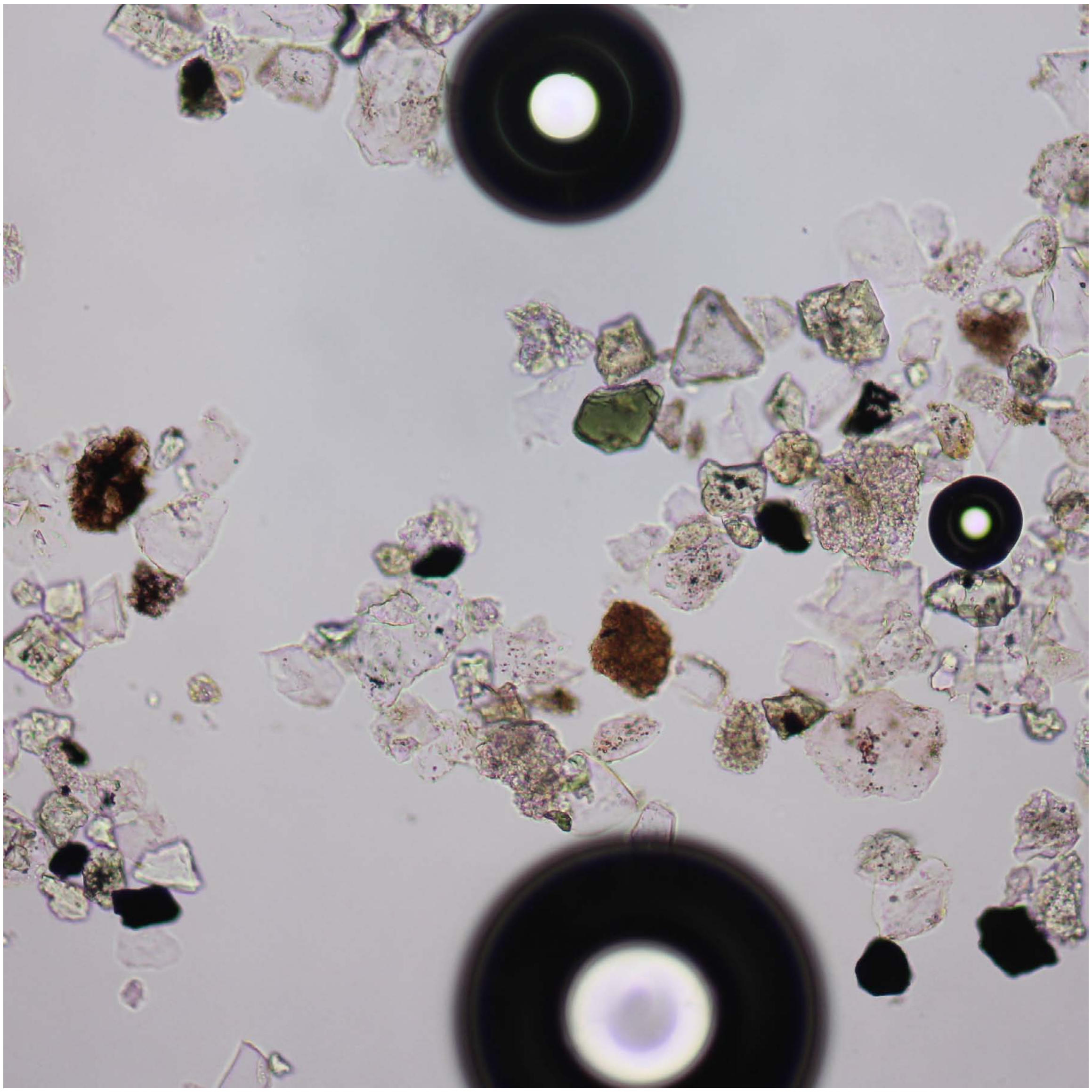


Silt tutorial 1a

Silt tutorial 1b

Silt tutorial 1c

Image ID: 0695/0696

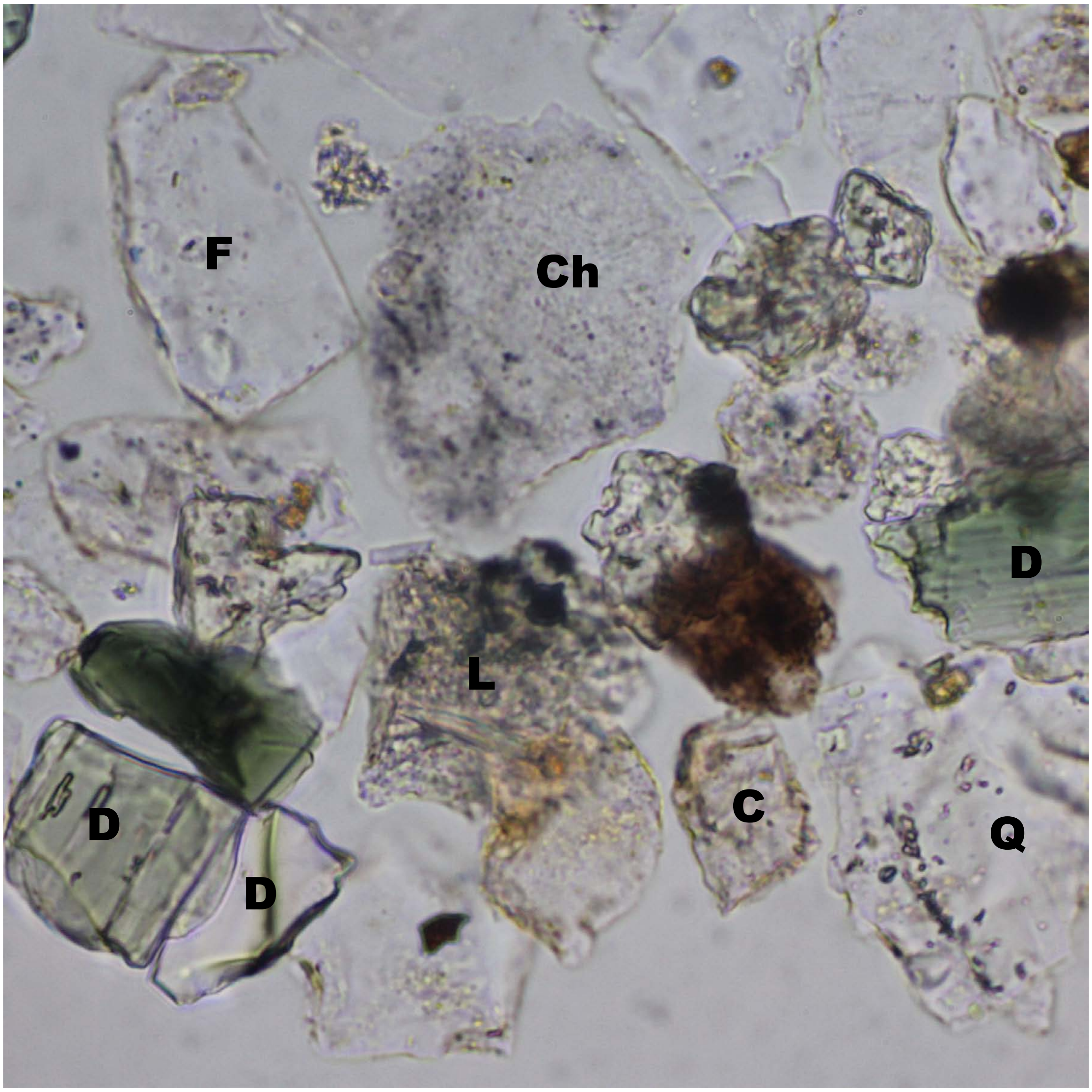


Silt tutorial 1a.

This low-magnification view shows sediment unevenly distributed across the slide. Dominating the view are several large bubbles that obscure underlying grains (see ghost of grain in lower center bubble). Roughly 33% of the view is filled with grains, ~5% of which are close to very fine sand in size, and there is no apparent clay-sized fraction. The grains can be subdivided by color, relief, and opacity in plane light. The high-relief transparent grains, under crossed nicols, show birefringence characteristic of carbonate and dense minerals exhibit lower birefringence. These dense grains are roughly 15% of the grains, an estimate calibrated to 33% of the field of view.

IODP/ODP/DSDP Sample: Hole 614A, Core 11H, Section 1W, 73.5 cm

Image ID: 0697/0698

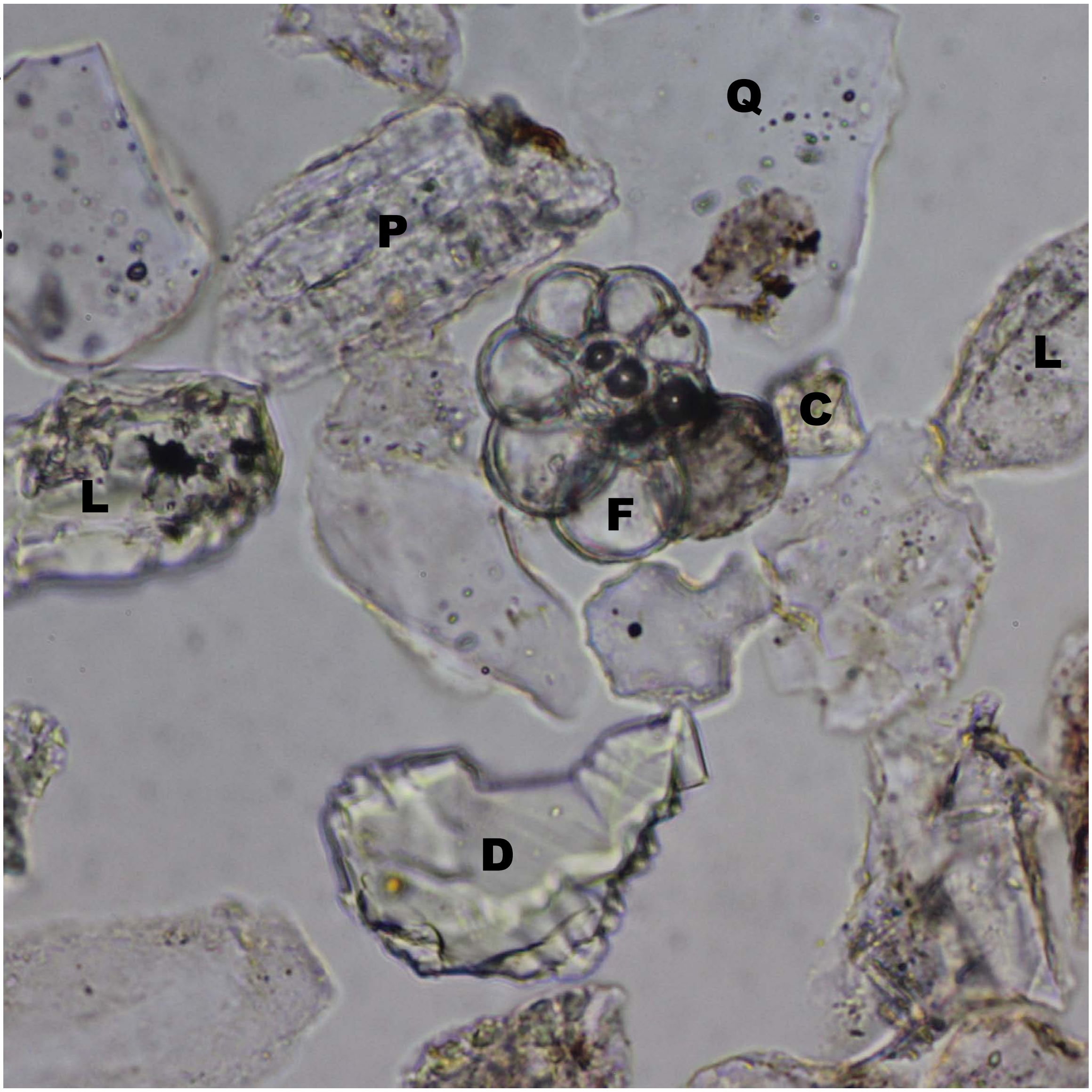


Silt tutorial 1b.

Approximately 80% of this field of view is filled with silt grains, a few ranging up to very fine sand size in one dimension. The largest grain is polycrystalline quartz or chert (Ch; 15%). Other major components are monocrystalline quartz (Q; 25%), dense minerals (D; 20%), potential feldspar (F; 15%), detrital carbonate (C; 10%), and lithic fragments (L; 15%). The dense grains exhibit low to no birefringence, with potentially garnet (colorless), and green amphibole or chloritoid. Lithic grains are of indeterminate origin, as is often the case in the silt fraction where small grain size does not provide sufficient detail.

IODP/ODP/DSDP Sample: Hole 614A, Core 11H, Section 1W, 73.5 cm

Image ID: 0707/0708



Silt tutorial 1c.

Approximately 70% of this field of view is filled with silt grains. A foraminifer (F; 10%) takes center stage in this image, noteworthy because it is filled with carbonate cement, suggesting that it may be recycled from older, partly cemented, sedimentary deposits. The major components are monocrystalline quartz (Q; 50%), lithic fragments (L; 15%), vaguely twinned feldspar (P; 10%), carbonate (C; 5%) and a dense mineral (D; 10%) possibly pyroxene. The latter exhibits dissolution/etch cockscomb texture.
IODP/ODP/DSDP Sample: Hole 614A, Core 11H, Section 1W, 73.5 cm

Mud Tutorial 1

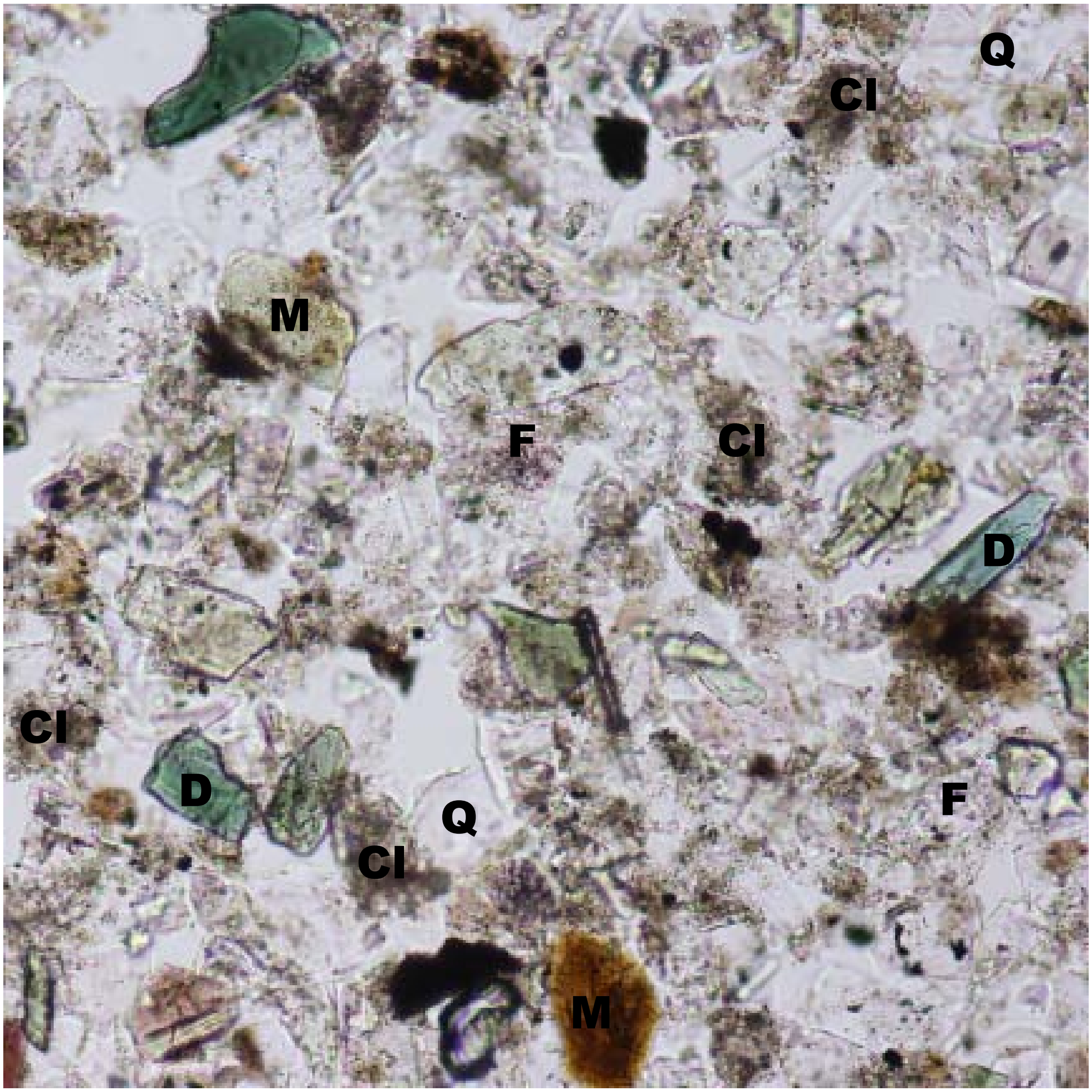
This sample is a mix of silt- and clay-sized mineral matter from the recently glaciated Chilean forearc. We chose this sample because it has clay-sized mineral matter in the clay-sized fraction that is likely a product of glaciation (glacial flour). The three views (1a, 1b, 1c) show more clay-rich (1a) and silt-rich (1b) areas at higher magnification as well as semicohesive clumping of material (1c) at lower magnification.

Mud tutorial 1a

Mud tutorial 1b

Mud tutorial 1c

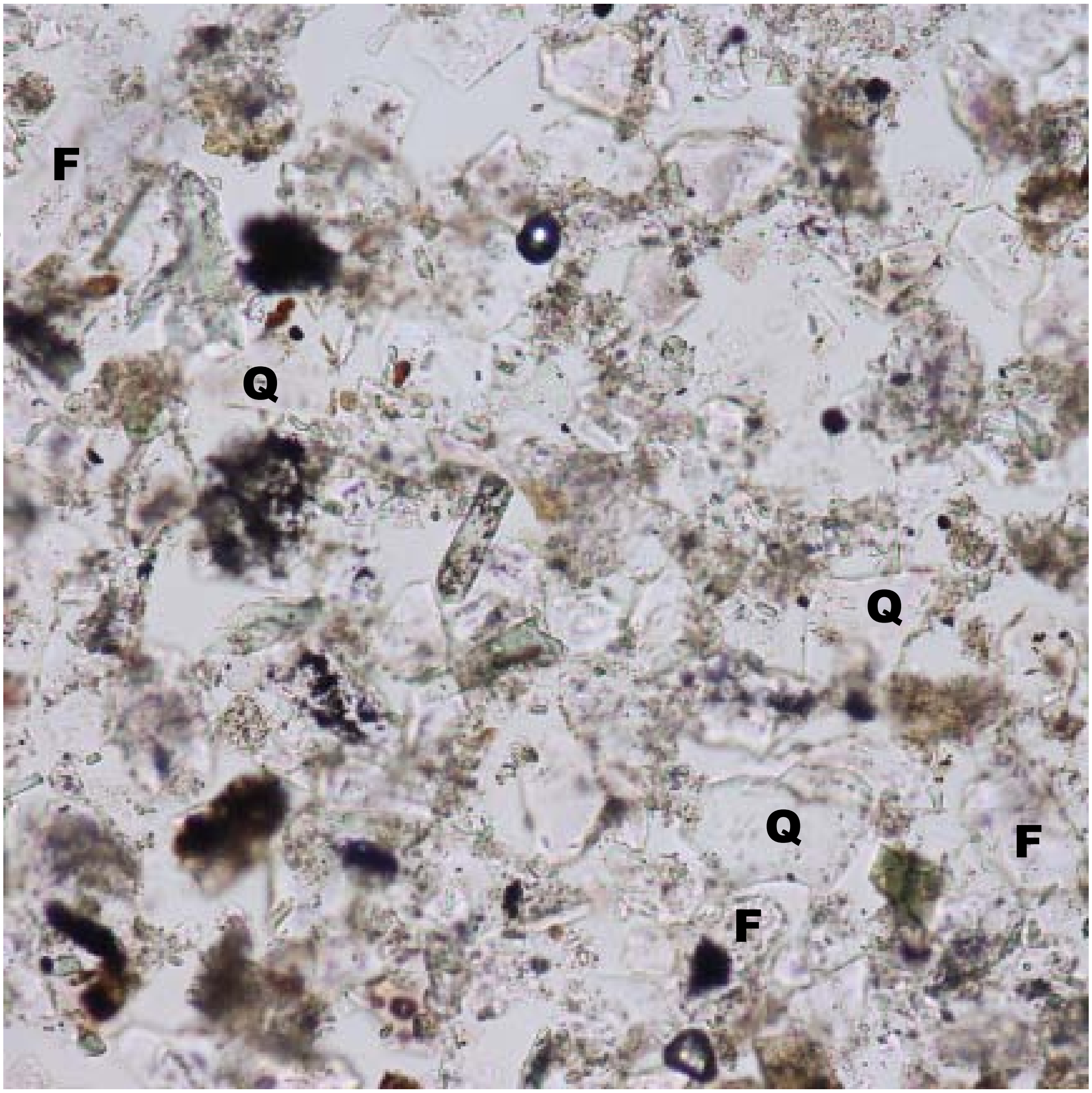
Image ID: 0166/0167



Mud tutorial 1a.

The sediment in this field of view is somewhat densely packed with little interstitial void space (estimated to be 15%). This sample has a “dirty” appearance because of the presence of clay minerals (nonbirefringent?), clay-sized mineral material (birefringent), as well as silt grains (with low birefringence) that appear dirty and are likely feldspar altering to clay minerals (F). In plane light, these minerals are not easily discriminated from clumps of clay-sized material (Cl). We consider these clumps to be a result of floccing rather than sedimentary lithic fragments. Thus estimates of grain proportions must be made by consulting both plane and crossed-nicols views. The field of view includes 5% green dense (D) minerals (amphiboles?), subequal percentages of quartz (20%) and feldspar (20%), significant clay-sized fines (35%), as mentioned above, and void space averaging 15%. Trace amounts of opaque minerals, high-relief dense minerals, micas (M), and volcanic lithics make up the remaining 5%. The silt grain-to-clay ratio indicates this is “clayey silt.”
IODP/ODP/DSDP Sample: Hole 861A, Core 1H, Section 5, 61 cm

Image ID: 0164/0165

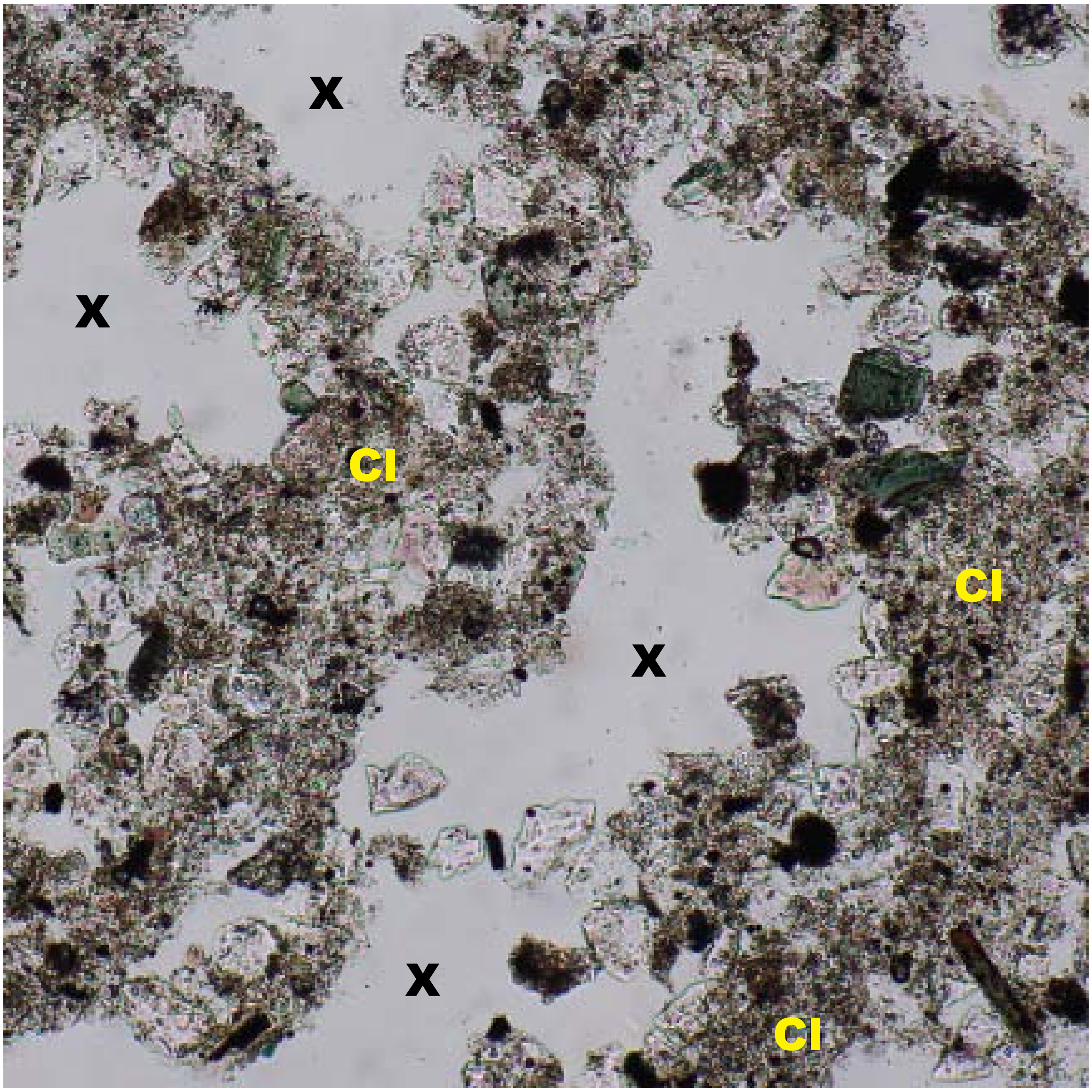


Mud tutorial 1b.

In contrast to the part of the slide shown in Mud Tutorial 1a, another location on the slide shows a similar, subequal ratio of quartz to feldspar with few dense minerals. Darker clumps are likely lithic fragments. The estimated relative percentages are: void space, 15%; quartz (Q), 20%; feldspar (F), 20%; clay-sized material, 40%; and other lithic (L), mica (M), and dense grains, 5%.

IODP/ODP/DSDP Sample: Hole 861A, Core 1H, Section 5, 61 cm

Image ID: 0179



Mud tutorial 1c.

This lower-magnification view shows clumping and bridging of grains caused by flow under the cover glass and floccing of the clay-sized fraction. Note the darker appearance of certain areas caused by increased density of clay minerals (Cl) and large areas of void space (X). Note that there is no view with nicols crossed.

IODP/ODP/DSDP Sample: Hole 861A, Core 1H, Section 5, 61 cm

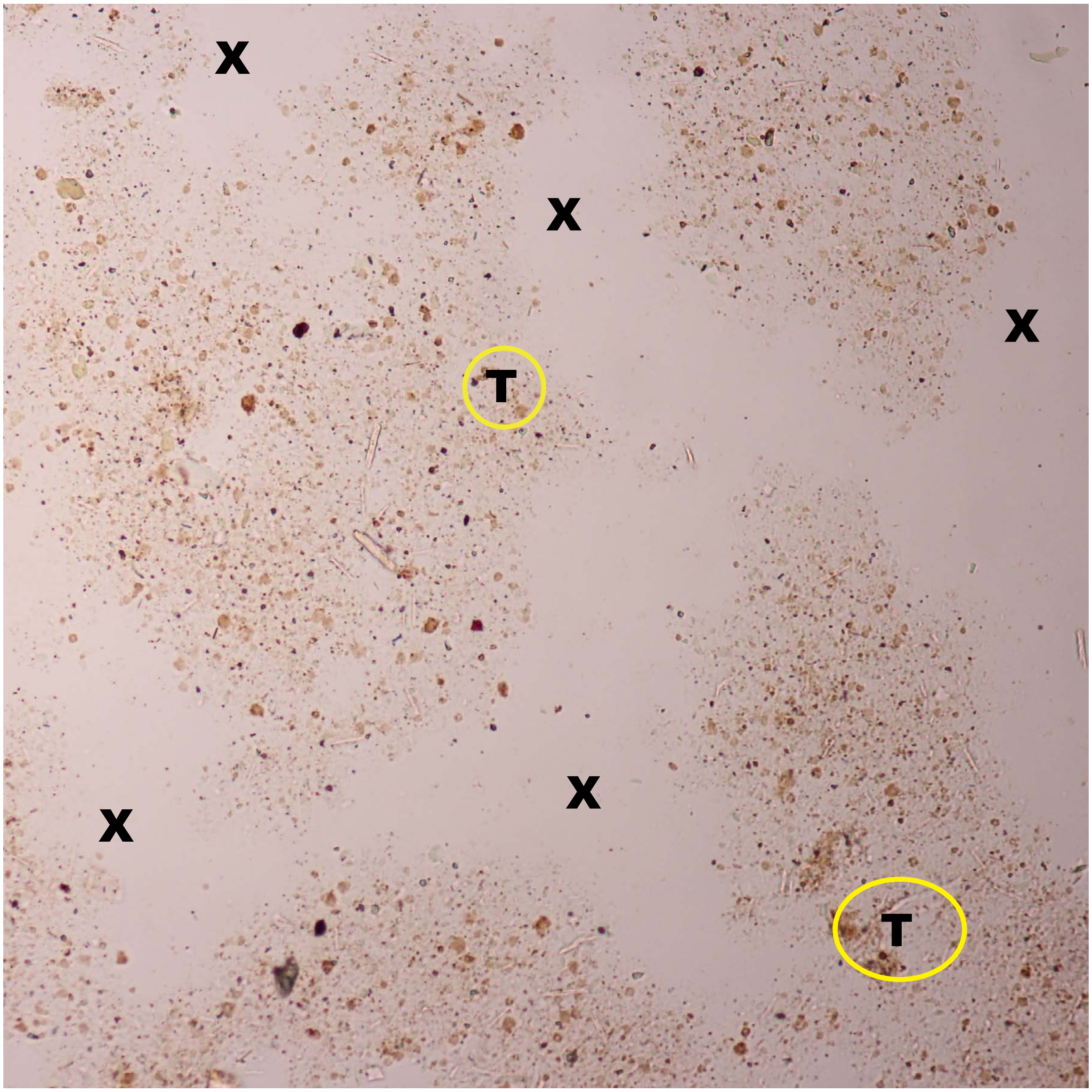
Clay Tutorial 1

This deep-sea marine clay is yellowish brown in hand specimen owing to the presence of authigenic Fe and Mn oxyhydroxides. Shipboard and postcruise analyses show that this lithology consists of 80% clay-sized material, placing it on the clay/claystone boundary. The clay and silt fractions are eolian in origin, consisting of clay minerals (70%), quartz (20%), and other components (10%), including amorphous phases such as Fe and Mn oxyhydroxides. Some authigenic clay, e.g., palygorskite, is present.


Clay tutorial 1a


Clay tutorial 1b

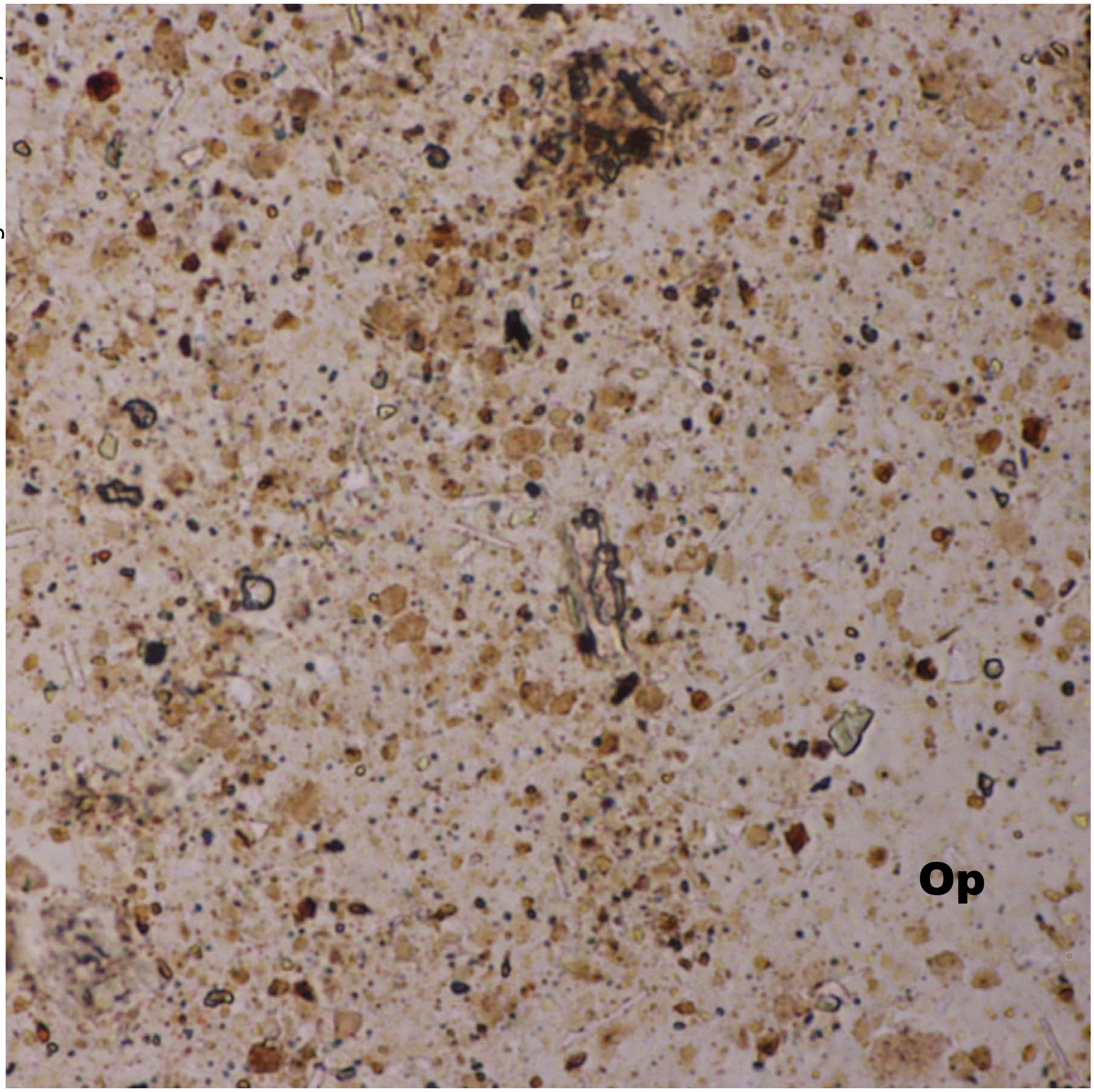
Image ID: 0430/0431



Clay tutorial 1a.

This low-magnification field of view shows the lack of sand-sized material in this sample. The cohesiveness of the clay likely accounts for its tendency to clump on ~70% of the slide, leaving large sediment-free areas. The density of material varies within the clumps as indicated by color variability, from light to dark. Larger gray to white, birefringent, silt-size grains are quartz/feldspar or fibrous toothpick (T) fragments. Note large areas of void space (X).
IODP/ODP/DSDP Sample: Hole 576B, Core 3H, Section 6W, 68 cm

Image ID: 0428/0429



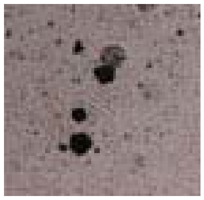
Clay tutorial 1b.

This is a higher-magnification view of one of the more densely packed clumps of material on the slide, where density decreases from left to right. Again, silt-sized fragments of birefringent toothpick, quartz, and dense minerals are present, the latter identifiable by their higher relief and slightly green color. Some of the birefringent minerals are likely clay minerals, given their high (70%) proportion in X-ray diffraction analyses of these sediments. The reddish-brown material is amorphous Fe and Mn oxyhydroxides. XRD data indicate these oxyhydroxides make up 10% of the sample. The higher apparent percentage of oxyhydroxides in most of the slide can be attributed to sediment density; this shows that there is an optimum sediment density on the smear slide for estimating percentages, in this case, best exemplified in the lower right corner of the field of view (Op), where the oxyhydroxides make up about 10-20%.
IODP/ODP/DSDP Sample: Hole 576B, Core 3, Section 6, 68 cm

Clay Tutorial 2

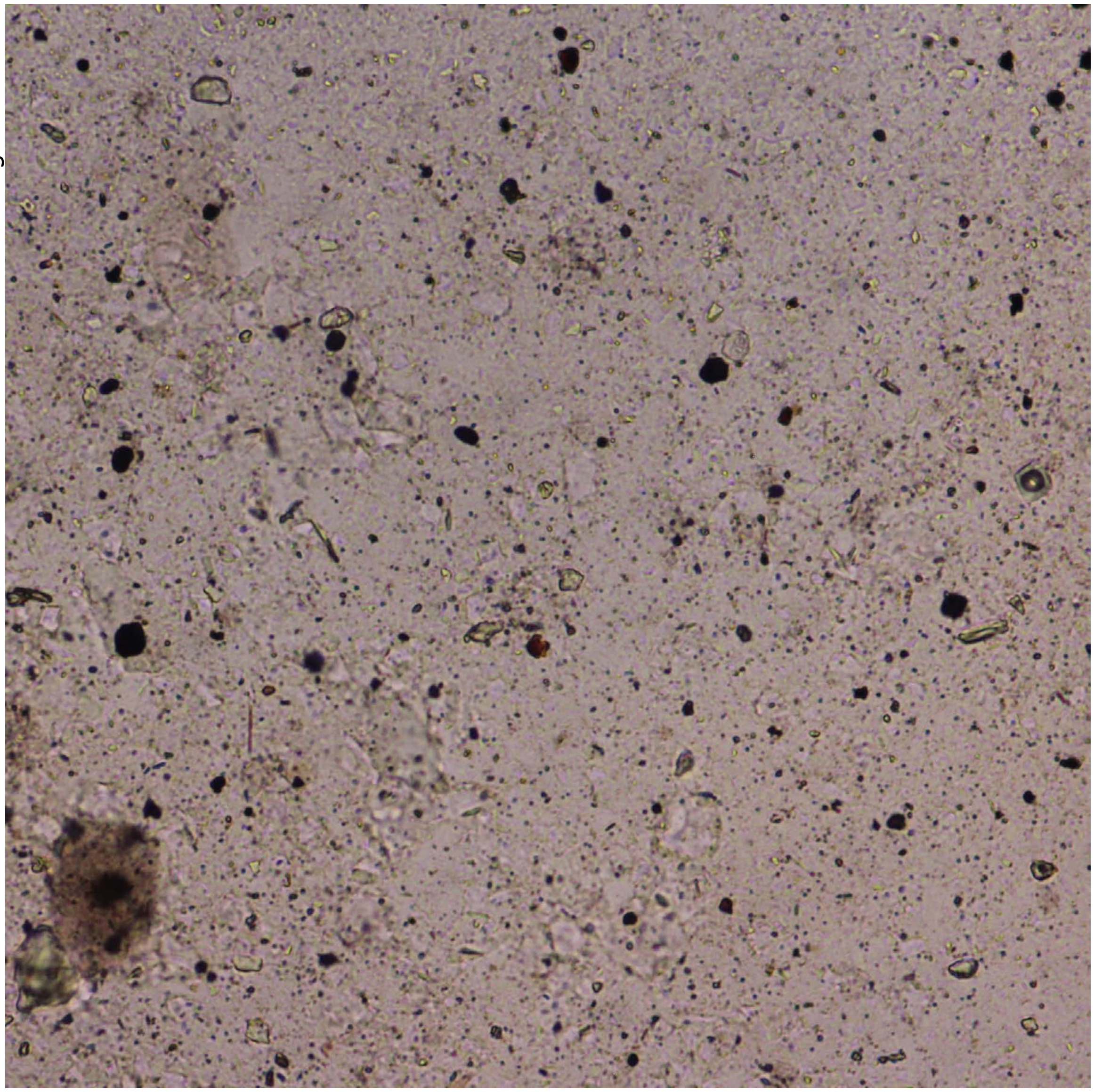
This sample is metalliferous, oxidized clay that overlies semimassive sulfide deposits on the Juan de Fuca Ridge. Its components, based on shipboard observations and analyses, are mainly clay-sized, authigenic phases such as nontronite, smectite, and Cu-Fe sulfides.

Clay tutorial 2a



Clay tutorial 2b

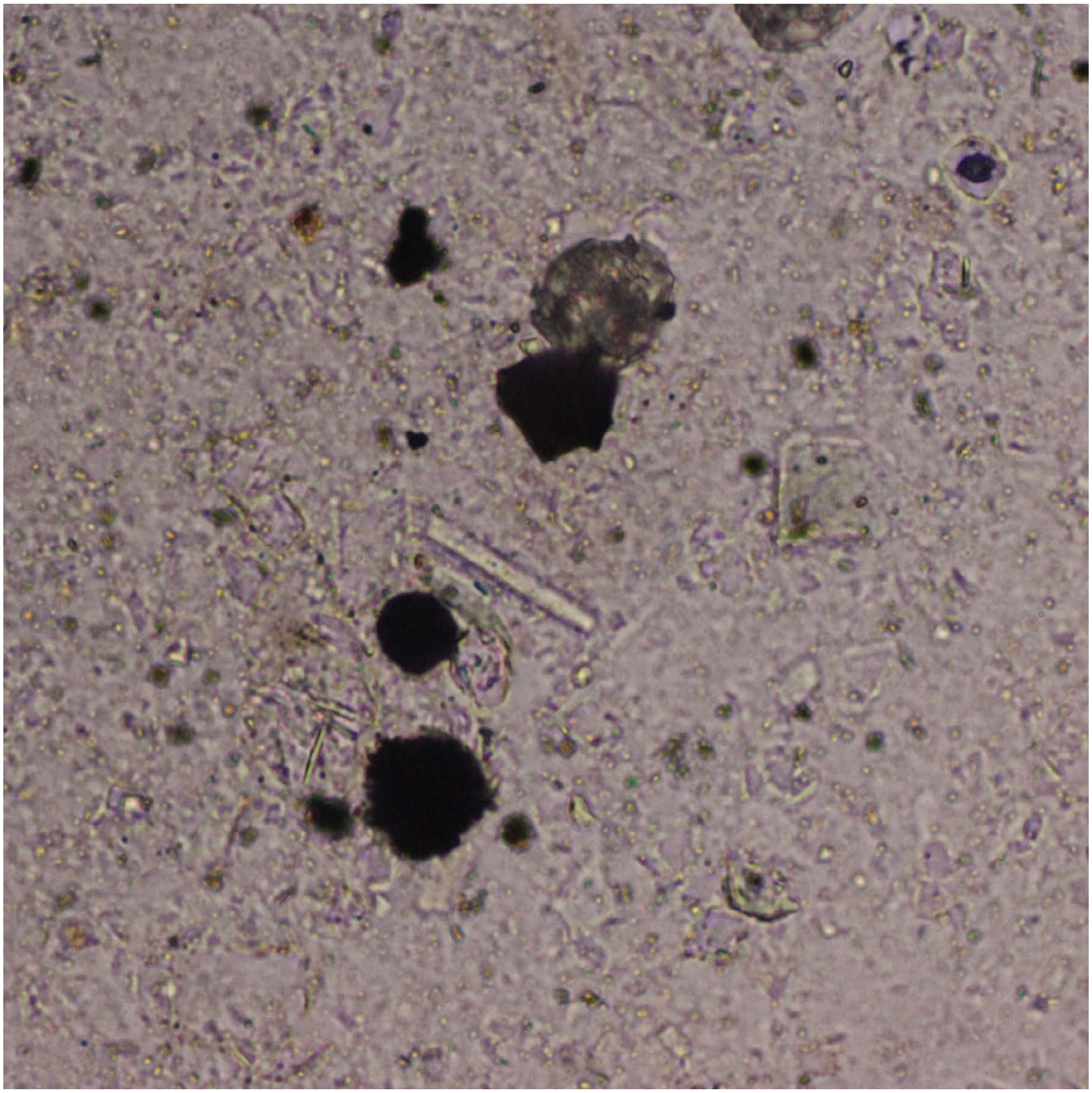
Image ID: 0525



Clay tutorial 2a.

This field of view comprises mostly clay-sized material with 5% silt-sized material, including authigenic opaques. The mineralogy of such fine-grained clays is best determined by X-ray diffraction. Note there is no view with nicols crossed.
IODP/ODP/DSDP Sample: Hole 858B, Core 2H, Section 2W, 37

Image ID: 0523



Clay tutorial 2b.

The sediment density in this area of the smear slide is fairly high with a closely packed clay fraction. At this higher magnification, opaque (black) sulfides seem to form framboids (clusters of smaller crystals) that make up ~3% of the field of view. The mineralogy of the other silt-sized minerals (<2%) is indeterminate. Note that there is no view with nicols crossed.

IODP/ODP/DSDP Sample: Hole 858B, Core 2H, Section 2W, 37 cm

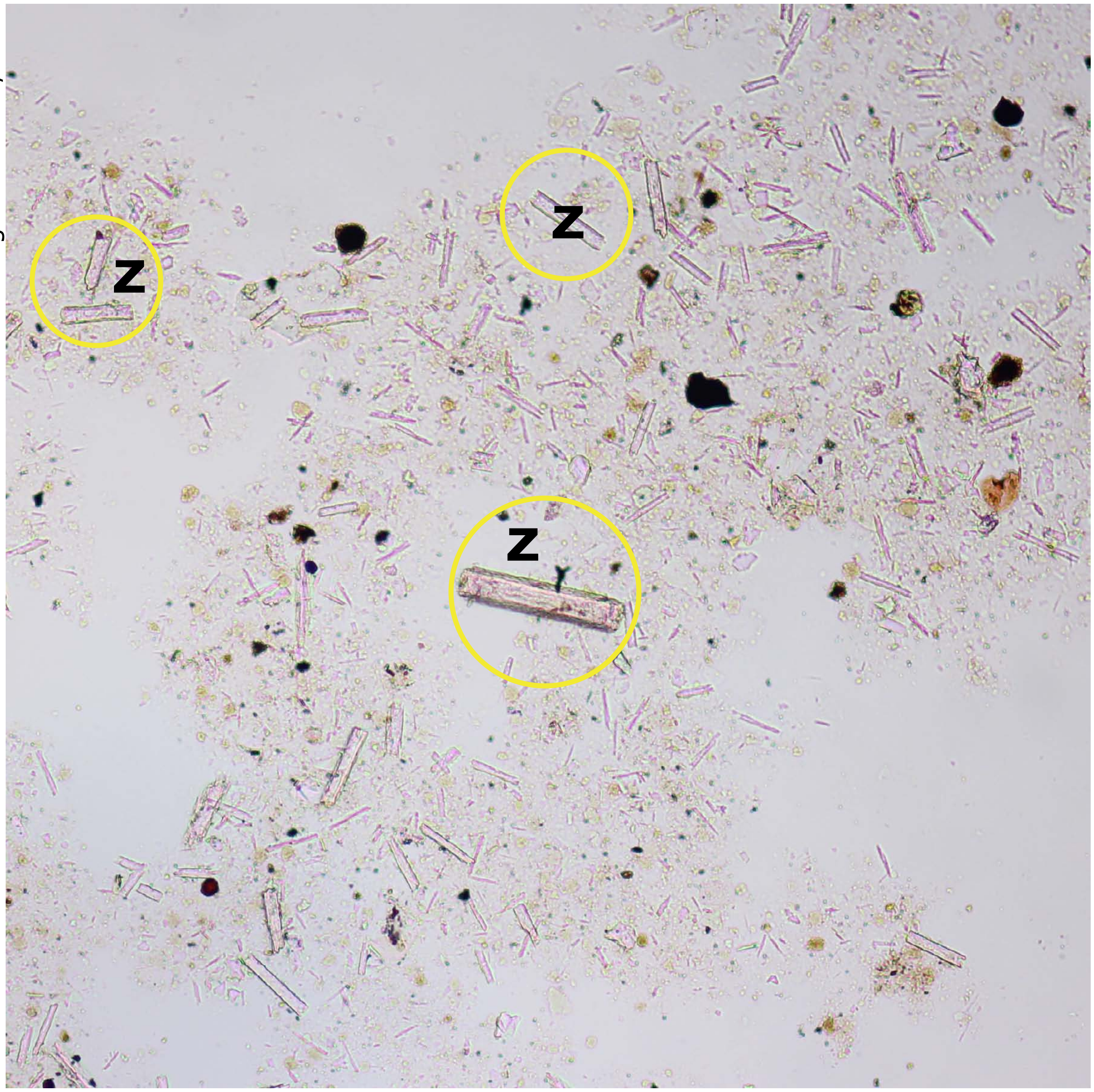
Clay Tutorial 3

This sample of zeolitic clay from the Hawaiian arch in the central Pacific is from a stratigraphic section that contains Hawaiian landslide debris. Trace amounts of fine Fe oxides give the mud a reddish-brown hue.

Clay tutorial 3a

Clay tutorial 3b

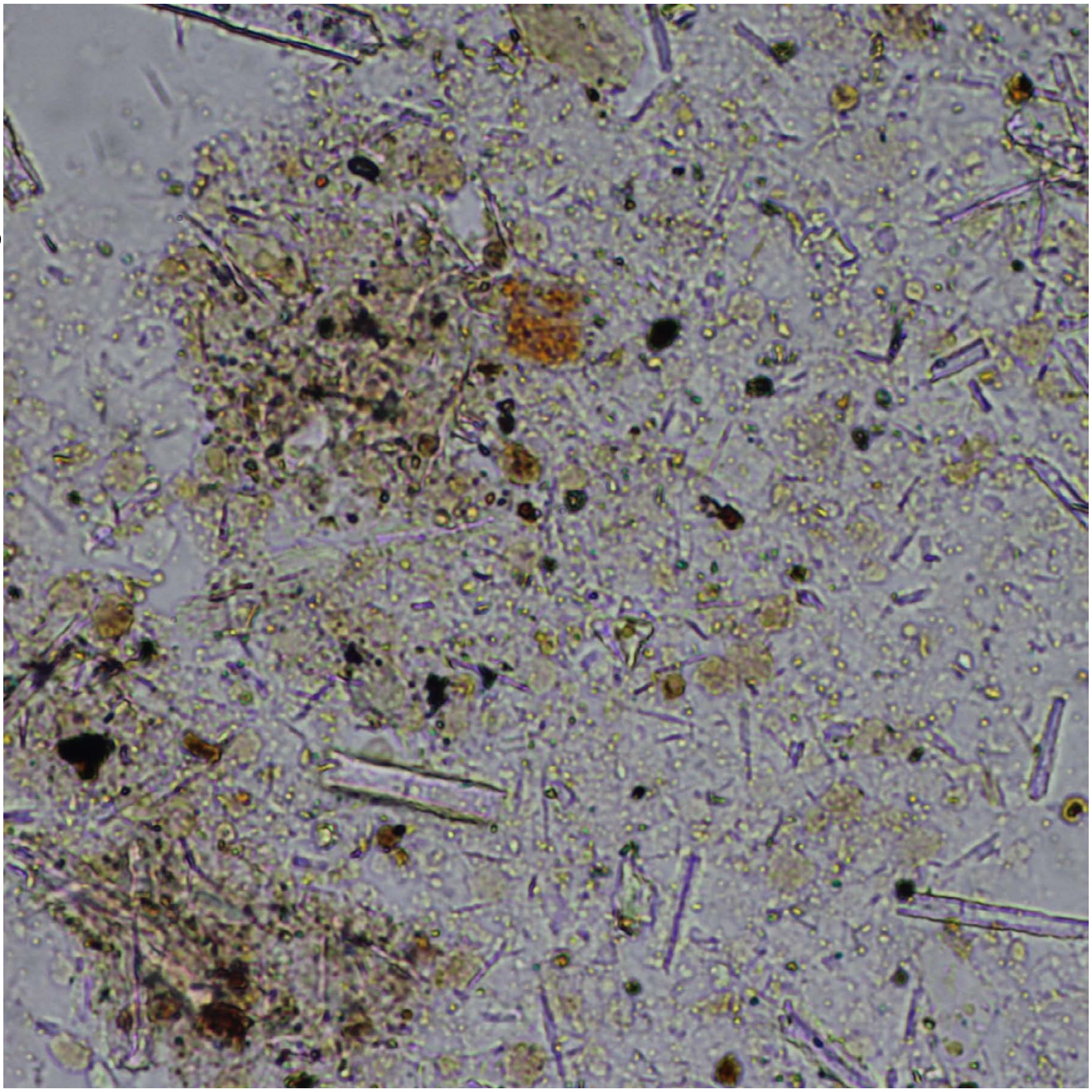
Image ID: 0495/0496



Clay tutorial 3a.

Roughly 70% of this general view is covered by fine sediment (dusty appearance in plane light and birefringent with nicols crossed). Of this sediment, roughly 93% is clay, 5% elongate authigenic crystals of zeolites (Z), 1% opaque minerals, and <1% Fe oxides (bright orange with nicols crossed). Some of the birefringent matrix may comprise clay minerals and carbonate (nannofossils, authigenic?). The birefringent coatings (circled) on some zeolite crystals indicate the presence of authigenic clay minerals (palygorskite?), but shipboard scientists only report phillipsite in their X-ray diffraction results.
IODP/ODP/DSDP Sample: Hole 842B, Core 3H, Section 4W, 66 cm

Image ID: 0499/0500



Clay tutorial 3b.

This close-up view shows the details of birefringent clay(?)-coated, rectangular zeolite crystals that make up 5% of the sample. Several darkish "clumps" of material on the left are a result of incomplete disaggregation and may be a product of incipient cementation, given their higher birefringence (indurated intervals and nodules were noted in the core).
Fe oxides (<1%)are reddish-brown in plane light and bright red(?) with nicols crossed.
IODP/ODP/DSDP Sample: Hole 842B, Core 3H, Section 4W, 66 cm