Smear slide identifications: the practical basics

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Smear slides provide instantaneous semi-quantitative compositional information so that one can accurately describe sedimentary units in a core before any sampling, or geochemical and mineralogical analysis, is performed.

Components:

Organic matter
- Terrestrial (allochthonous)
- Aquatic (autochthonous)

Minerals
- Allogenic (clastic, detrital: mostly silicates)
- Authigenic (carbonates and other salts precipitated in the lake)
- Diagenetic (sulfides, phosphates, and other minerals formed in the sediments)

Algal remains not composed of organic matter
- Diatom frustules (silica)
- Sponge spicules (silica)
- Chrysophyte cysts (silica)
- *Phacotus* loricae (calcite)

Many of the biological indicators used in paleoecological studies (e.g., pollen and ostracodes) are relatively rare and are not usually seen in smear slides. In practice, in midwestern lakes like we're looking at today, we usually have a three- or four-(major-)component system:

1. Organic matter
2. Diatom frustules
3. Clastic material (sand, silt, clay)

(with or without:)

4. Authigenic carbonate (usually calcite)

One of the reasons for separating components in this way (for example, treating diatoms as their own category rather than with other biological remains) is to make smear slide data readily comparable with routine geochemical analyses such as loss-on-ignition, carbonate and organic carbon coulometry, and biogenic silica measurement.

Let's take these components one by one.

1. **Organic matter** ranges from unrecognizable, amorphous, decomposed algal remains (the dominant pelagic organic component), to insect and other animal parts, to aquatic macrophyte and terrestrial plant parts with identifiable structures such as cellular tissue, pollen grains, and phytoliths (silica bodies formed within grasses). Terrestrial plant material of all types may also be found as small charcoal fragments, identified by their black color and iridescent luster.

In smear slide you may see a lot of blobby brown clumps, frequently agglomerated with clay, carbonates, and other particles. These are the remains of phytoplankton (chlorophytes, cyanobacteria). Fibrous and other structural plant remains, including charcoal, may be identifiable to taxon by an expert, but in basic smear slide analysis are simply used as indicators of varying bulk terrestrial inputs and lake level changes (advance and retreat of the shoreline and shallow water environment relative to the sampling location).

2. **Diatoms** are a ubiquitous component of the lacustrine and marine algal flora. Their silica cell walls (frustules) are sometimes dissolved in high-pH and other silica-undersaturated bottom water environments; when preserved, their ornamented frustules can be identified to species and used to reconstruct paleo-water chemistry based on the ecological tolerances of various species. Pennate diatoms (typically benthic) are bilaterally symmetrical, while centric diatoms (typically planktonic) are radially symmetrical.

A higher powered objective and some special training are required to identify diatoms to species, but basic observations in smear slide such as species richness or lack thereof (diatom blooms generating monospecific layers are common), pennate/centric ratio, and quality of preservation can be useful.

3. **Clastic material** includes all the detrital mineral grains washed into the lake by runoff and surface water inputs. (For our purposes, we include terrestrial organic material above with other organics, rather than with the clastic mineral component, although some workers refer to macroscopic plant remains as "detritus.")

Grain size is the main observation you should make wth respect to clastics. Variations in grain size are indicative of different facies (environments of deposition), and specifically of distance to shore and modes of sediment transport (by sublacustrine currents, wave reworking, storms, aeolian deposition, etc.). Note that the microscope has a reticule (eyepiece micrometer) and a cheat-sheet indicating the size of the graduations for each magnification. Recall from your basic sedimentology the size ranges of particles:

Clay: <4 μm
Silt: 4 – 63 μm
Sand: 63 μm – 2 mm
Gravel: >2 mm

We are not likely to get anything over about 500 μm in smear slide due to the limitations of slide thickness, but larger particles will show up in coarse fractions. Use the ternary diagram on the smear slide sheet to indicate the relative fractions of sand, silt, and clay.

Identifying the constituent clastic minerals may or may not be important: if you are working in a basin fed by several streams draining regions of different geology, variations in mineralogy may indicate varying contributions of those watersheds; if the lake is situated within homogeneous glacial till and outwash sand, the mineralogy will probably not tell you anything that changes over time. Differentiating between **quartz** and **feldspar** (which have similar color in crossed nicols) is relatively easy: quartz, unlike feldspar, has no cleavage, so will very rarely have straight edges on grains. Clastic **carbonates** (i.e., carbonate particles derived from limestone bedrock or calcareous till) are sometimes a significant fraction of the sediment, and are important to differentiate from authigenic calcite because they will have a different isotopic signature. Luckily, it is fairly easy to distinguish detrital grains (which are relatively large and irregularly shaped) from rhombic authigenic calcite, which is rarely over 30 μm in diameter and is typically much smaller. Physically separating the two is harder . . .

4. **Carbonate** minerals produced in the lake surface waters are important and widely-used indicators of past water chemistry and biological productivity. As noted above, grain size ranges from sub-micron (sometimes termed "micrite") to a few tens of microns. Calcite precipitated in open water and preserved well in the sediments is typically rhombohedral; other carbonates may be shaped more like rice grains or short needles. The primary way to identify carbonate minerals in smear slide is by their high birefringence, or "sparkle," when viewed in cross-polarized light. It can be hard to distinguish between very fine carbonate and clay in smear slide, but in the carbonate will show up as brighter points of light.

No carbonates: dilute, low-alkalinity waters, and/or corrosive bottom waters.
Low-magnesium calcite ($CaCO_3$): moderate alkalinity, Ca^{2+} is dominant ion.
High-magnesium calcite; aragonite ($CaCO_3$): higher alkalinity, higher Mg/Ca ratio.
Siderite ($FeCO_3$): alkaline, reducing bottom waters (to get Fe^{2+}), often in low-Ca, high-Fe systems; probably produced at oxic/anoxic interface at time of lake overturn.
Carbonates in which the cation is *manganese or magnesium* (or in which some of another cation is replaced with these or with iron) are also known from lake sediments but are typically restricted to specific lake types and regions.

Weirdo and uncommon components . . . just a few:
Vivianite: diagenetic iron phosphate mineral. Turns from white to bright blue as it oxidizes after a core is split. Appears as pale blue prisms or sprays in smear slide. Pictured on website.
Mica: Plates, flakes, long strands. May have high birefringence in smear slide. Pictured on website.
Phacotus: green alga with a calcite covering (lorica). Appears as a birefringent circle with a black cross (pinwheel, baseball seams) that turns as the stage is rotated.
Tephra: Volcanic ash; pointy (if fresh) or rounded (if abraded) glassy shards. Diagnostic feature that distinguishes them from angular silt-sized silicate grains is that they are isotropic (because they are glass and thus non-crystalline) and so disappear under cross-polarized light. Pictured on website.
Pyrite: Iron sulfide, diagenetic. May appear as tiny black spheres or cubes.

Identifying new phases, or things you haven't seen before
X-ray diffraction mineralogy (a common geological technique) can be used iteratively to identify unknown phases in smear slide, provided the mineral is common enough (>~5% of sediment, depending upon crystallinity of the mineral).

Also see: http://lrc.geo.umn.edu/smears/smear.html

"To the trained eye, all of the common rock-forming minerals are familiar friends and can usually be identified on sight."

Mineralogy: Concepts and Principles
Tibor Zoltai and James H. Stout