Reflected light microscopy of macerals

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1. Introduction

Topics:

- The maceral concept and maceral identification
  - The reflected light microscope
  - Measuring vitrinite reflectance

Reflected light microscopy of macerals

2. Macerals

Definition:
„Macerals are the smallest recognizable organo-petrographic entities in coal an other sediments using the optical microscope.“
Reflected light microscopy of macerals
2. Macerals - Classification

- They are identified by morphology, reflectance, colour and fluorescence
- Unlike minerals, macerals are not homogenous, but a mixture of similar (organo-chemical) compounds
- Macerals of similar reflectance (= similar chemistry) are grouped in three maceral groups each with its own maceral sub-groups and macerals

![Diagram of maceral classification]

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2. Macerals - Genesis

Vitrinite $\rightarrow$ Plant cell walls
Inertinite $\rightarrow$ Same as vitrinite but oxidized (Fire, bacteria, fungal activity, etc.)
Liptinite $\rightarrow$ Hydrogen-rich plant remains, i.e. resins, waxes, fats

Reflected light microscopy of macerals
2. Macerals - Genesis

Coalification – Two Stages

<table>
<thead>
<tr>
<th>Mire</th>
<th>Biochemical Stage</th>
<th>Geochemical Stage</th>
<th>Gellation</th>
<th>Polymerisation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peat</td>
<td>cell tissue intact</td>
<td>WOOD</td>
<td>TEXTINITE</td>
<td>TELINITE</td>
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<tr>
<td></td>
<td>cell tissue is</td>
<td>V</td>
<td>V</td>
<td>TELECOLLINITE</td>
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<td></td>
<td>slightly affected</td>
<td>V</td>
<td>V</td>
<td>DESMCOLLINITE</td>
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<td></td>
<td>cell tissue has</td>
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<td>V</td>
<td>GELO-COLLINITE</td>
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<tr>
<td></td>
<td>collapsed</td>
<td>V</td>
<td>V</td>
<td>TELOVITRINITE</td>
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<tr>
<td></td>
<td>disintegrated cell</td>
<td>V</td>
<td>V</td>
<td>DETROVITRINITE</td>
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<tr>
<td></td>
<td>fragments</td>
<td>V</td>
<td>V</td>
<td>GELOVITRINITE</td>
</tr>
<tr>
<td></td>
<td>humus colloids</td>
<td>V</td>
<td>V</td>
<td></td>
</tr>
</tbody>
</table>

| Lignite | Bituminous Coal |
|---------|-----------------
|         | mild TEXTO-ULMINITE | ATTRINITE | DETRO-EU-POR-PHASE |
|         | strong EU-ULMINITE  | DENSINITE | GELINITE          |
|         | V                 | V         | V                  |
|         | V                 | V         | V                  |
|         | V                 | V         | V                  |
|         | V                 | V         | V                  |
|         | V                 | V         | V                  |
|         | V                 | V         | V                  |
|         | V                 | V         | V                  |
|         | V                 | V         | V                  |
|         | V                 | V         | V                  |
|         | V                 | V         | V                  |
|         | V                 | V         | V                  |
|         | V                 | V         | V                  |
|         | V                 | V         | V                  |
|         | V                 | V         | V                  |
|         | V                 | V         | V                  |
|         | V                 | V         | V                  |
|         | V                 | V         | V                  |
|         | V                 | V         | V                  |

1. Biochemical stage: Depolimerization of biological macromolecules, i.e. cellulose
   Formation of humus colloids

2. Geochemical stage: Gelification and re-polymerisation
   Formation of vitrinite $\rightarrow$ Vitrification
Reflected light microscopy of macerals
2. Macerals viewed with the microscope

- The maceral groups are always differentiated by their relative reflectance:
  - Liptinites = dark gray to black
  - Vitrinites = medium gray
  - Inertinites = light gray to white

Taylor et al., 1998

Reflected light microscopy of macerals
2. Macerals viewed with the microscope

**Vitrinites**

Telovitrinite = Telinite + Collotelinite
(Maceral Subgroup) (Macerals)

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2. Macerals viewed with the microscope

Inertinites
Fusinite = Inertinite with preserved cell structure

Liptinites

Funginite (Sclerotia + fungal spores)

Suberinite

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Reflectivity or reflectance is the proportion of perpendicular incident light which is reflected from a surface.

It depends on the refractive index of the sample and immersion medium and the absorption coefficient of the sample.

This relationship is given in the Fresnel-Beer equation.

\[
R = \frac{(n - N)^2 - k^2}{(n + N)^2 - k^2}
\]

- \( n \) = refractive index sample
- \( N \) = refractive index medium
- \( K \) = absorption coefficient

In case of coal petrography the sample is analysed by linear polarized light with an immersion objective.

An immersion oil is needed to increase contrast, brightness and resolution.

The numerical aperture (NA) determines the collected amount of light.

\[
NA = n \sin(\alpha)
\]

The distance (d) at which two points are still optically seperable (resolution) is given by:

\[
d = \frac{\lambda}{2 \cdot NA}
\]
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3. Reflected light microscopy

Incident ray  →  Reflected ray

If the material is totally opaque, we only see the reflected ray.

If the material is partly translucent, we get a refracted/transmitted ray.

The refracted ray may get reflected at the next surface (grain boundary, impurities, crack, etc.) and leave the sample → inner reflex

Inner reflexes are often colorful and sometimes represent the streak color ('Strichfarbe') of the mineral.

Yellow to orange inner reflexes in Sphalerite (ZnS) 'Strichfarbe' – Yellow to brown

Vitrinite is not a crystalline substance, but behaves like an anisotropic crystall because of its molecular structure (similar arrangement of aromatic units). Such anisotropy is called 'form anisotropy'.

Due to the anisotropy, the linear polarized light experiences different absorption (depending on the angle between polarization and optical axes) which results in different reflectivities.

Thus, vitrinites show Bi-reflectance (or Reflectionpleochroism). This is only visible in linear polarized light!

Bi-reflectance gives two readings: $R_{\text{max}}$ and $R_{\text{min}}$.
3. Reflected light microscopy

Below a random reflectivity of about 2% $R_r$ and $R_{\text{max}}$ can be related as follows:

$$R_{\text{max}} = 1.066 \cdot R_r$$

4. Measuring vitrinite reflectance

- Reflected light is measured by a photometer at 546 nm
- Decide if maximum or random reflectance should be measured
- Calibrate the system by measuring reflectance standards
- Coal: Only Collotelenite is measured by point counting, usually 100 readings (500 recommended)
- DOM: Every vitrinite is measured, no point counting, often very few particles, 'measure as much as you can'
- Drift: Check the calibration every 15 – 20 minutes
Reflected light microscopy of macerals
4. Measuring vitrinite reflectance

Pitfalls

Vitrinite in DOM can be:
- Primary
- Reworked/recycled
- Cavings (borehole)

Can be confused with:
- Solid bitumen or Bituminite
- Semifusinite

- Angular
- No mineral inclusions
- Less bright than recycled
- Darker than vitrinite
- Irregular shape, often lenticular or wispy
- Has mineral inclusions
- Rounded
- Brighter than primary vitrinite