ICCP
COMMISSION II

Identification of Dispersed Organic Matter WG

2018 ROUND ROBIN EXERCISE – 2019 Final Report

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Introduction

The aim of the Identification of Dispersed Organic Matter WG (IDOM WG) is to test the applicability and restriction of the existing terminology of liptinite macerals in whole rock samples and to constrain, if required the existing terminologies and definitions of liptinite macerals in identification of dispersed organic matter.

Following an announcement of a proposed new round robin exercise during the 67th ICCP Conference in Potsdam in 2015 (see ICCP News 63, 2015, p.26), a whole rock sample and kerogen concentrate, containing bituminite macerals were prepared for the 2016 IDOM round robin exercise. The 2016 IDOM round robin exercise was performed on whole rock sample and kerogen concentrate. In addition to a definition of bituminite of ICCP (Pickel et al., 2016), guidelines for the round robin exercise and bituminite description sheet were sent to the participants interested to perform the exercise.

Twenty-three ICCP participants were invited in November 2018 to participate in the 2018 IDOM round robin exercise (see e-mail from 05. November 2018). The whole rock samples were prepared at the Coal and Organic Petrography Laboratory of the Federal Institute for Geosciences and Natural Resources, (BGR), Germany.

Preparation of samples

Prof. Paul Wignall collected the Kimmeridge Clay rock sample in 2018 at the Filey Bay located in North Yorkshire, UK. Following drying at 25°C in nitrogen-flushed drying oven, the sample was ground to approximately 1-2 mm in size and homogenized. Aliquots of the sample were sent to participants for preparation of whole rock pellets.

The Kimmeridge Clay rock sample from the Filey Bay provided difficulties in preparation of polished whole rock pellets as reported by some participants. The conventional preparation steps using silicon carbide or aluminum oxides with water, as a polishing agent appears to be at least in some cases non-entirely adequate for sample preparation according to national standards such as for example the ASTM D2797: Preparing coal samples for microscopical analysis by reflected light (ASTM, 2007). The encountered difficulties involved:

1. Essentially difficulties for encountering polished elements at surface are shown, along with incoherent boundaries and very high dark rims indicating strong polishing relief.
   Under fluorescence light it is still possible to identify the components but measurements will be unrealistic due to the combination of small size, high relief and possible inclination of the surface. I encountered big difficulties to analyse the sample when polished under water using standard preparation techniques. Very few particles were suitable to take a measurement and even in these cases, it was not clear whether the particle was totally horizontal or inclined due to the lack of coherence with the mineral matrix. A second attempt was done to polish the sample with polishing oil and cleaning it with alcohol at the end. This procedure has typically a less perfect ending for the surface but reduce the problems of incoherence with the minerals. Many more particles were available for polishing in this case.

2. Unfortunately, as you will see in my remarks, the lab that prepares the blocks for me did a poor job this time (not usual case) probably due to some swelling clays in that sample. It was only today that I found out because I had not checked the block before and too late to re-polish it now. The quality is nearly unacceptable and I worked my eyes out today trying to find some acceptable spots to measure. Therefore, confidence is low

3. Some difficulties were encountered in the process of assembling the polished section, mainly that related to the polishing process, since the organic material is very dense.

4. The technician reported previously that the polishing of the marl type of rock sample was very hard. The final polished surface was not in one surface.The rock particles surface was very much uneven and undulating where some layers was more resistant to polishing. From the point of view of macerals identification and reflectance measurements the polishing of the particles have good or at least acceptable condition in most cases. Because of the holes and uneven surface of polished block the finding of suitable particle was quite hard.

5. The sample preparation is not ideal, and contains high relief within rock fragments and many plucks of individual fragments. The poor examination surface may suggest presence of swelling clays (and therefore low thermal maturity) which are impacted by water lubrication during preparation. Considering the ASTM D7708 reporting requirements, sample preparation is scored as 3B (a minority of the sample examination surface is usable and within it, >50% of the organic matter is free of pitting, scratching and excessive relief).

Sample information

The Kimmeridge Clay (Upper Jurassic (Kimmeridgian) in North Yorkshire is dominated by marine mudstones and thin limestones. It is of marine origin with about 300 m of thick section preserved in the North Yorkshire Basin (Gallois, 1979). It is rich in ammonites, bivalves, and foraminifera. Gastropods, serpulids, crinoids, belemnites and coccoliths are also abundant. Palynomorphs, including dinoflagellate cysts, pollen, and spores are also present.

According to the Organic Geochemistry Laboratory of the Federal Institute for Geosciences and Natural Resources, (BGR), the Kimmeridge Clay rock sample is an organic-rich sample with TOC of 8.62 wt. %, Tmax of 418°C, and S2 of 46.44 mg HC/ g-rock.

Objectives of the 2018 IDOM WG Round Robin Exercise

The objective of the 2018 IDOM WG Round Robin Exercise was to:

1. Measure random vitrinite reflectance VRr (%) in whole rock sample in accordance to ASTM D7708, providing:
   a. VRr (%) with 3 decimal numbers,
   b. number of measurements,
   c. Standard deviation (SD) with 4 decimal numbers.

2. Measure random bituminite reflectance BRr (%) in whole rock sample in line with the ASTM D7708, applying the procedure for random reflectance measurements on bituminite macerals, providing:
   a. BRr (%)with 3 decimal numbers,
   b. number of measurements,
   c. Standard deviation (SD) with 4 decimal numbers.

3. Identify encountered bituminite maceral(s) in the whole rock sample in accordance to the approved and provided ICCP terminology of bituminite (Pickel et al., 2017),

4. Provide a description of bituminite in accordance to the supplied bituminite description sheet.

Vitrinite reflectance in whole rock

20 participants performed the measurements of random vitrinite and bituminite reflectances in whole rock sample. The obtained random vitrinite reflectance values for the whole rock sample range from 0.23 to 0.70% VRr with a group mean (GM) reflectance value of 0.47% VRr (Fig. 1).
The scatter in the values is large as reflected by the group SD of 0.109 for vitrinite, indicating that some participants had difficulties in identifying representative vitrinite particles. Values marked in red indicates a large SD (>0.1), whereas data points in yellow show anomalously low reflectance values (≤0.23). Most participants measured an average of 37 vitrinite particles.

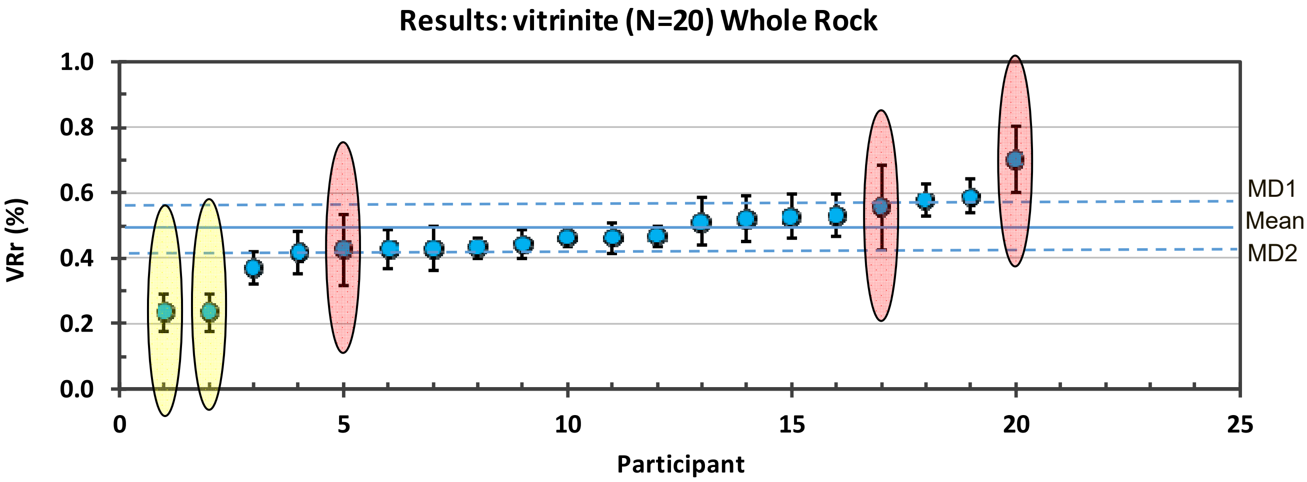

Fig. 1. Distribution and scatter of random vitrinite reflectance values. The solid line correspond to the mean and the dotted lines to the modal values shown in Fig 2. The yellow marked values indicate anomalously low values and the data points in red mark a large SD (>0.1).

The random vitrinite reflectance values displayed in Fig 2 are presented in a histogram with a 0.025 class width. The 0.450 and 0.570% VRr peaks reflect a clear bimodal distribution of mean vitrinite reflectance values reported by participants.

A cross plot between the random vitrinite reflectance (VRr) and vitrinite standard deviations (VSD) for whole rock sample as displayed in Fig. 3 shows a clear bimodal distribution of the measured reflectance values. Three data points, with extremely high SD, marked red, are interpreted as possible mixed populations. Two extremely low values of 0.23 % VRr, suggest a non-vitrinite origin, possibly bitumen. It is also possible that these low values are resulting from an inaccurate measurement due to unevenly polished surface resulting from poor polishing.

With the exclusion of the five data points characterized by the extremely high VSD and the extremely low mean reflectance values (VRr), the remaining group have a statistically accepted average SD of 0.057. This suggests that these participants did not have difficulties identifying vitrinite particles, despite the problems encountered during the polishing stage of sample preparation. The variation or bimodality of the measured average vitrinite reflectance maybe due to nature of the vitrinite particles being measured. Based on Fig. 2, the first vitrinite population with a mean at 0.450% VRr can be assign either to indigenous vitrinite or to vitrinite impregnated with bitumen. Their origin is not particularly clear and requires further in-depth analysis. Petrographic analysis show that these measured particles have sub-rounded and sometimes fissured physical properties. The higher reflecting population with a mean VRr of <0.575 are more than likely indigenous vitrinite. The remaining data point with VRr of >0.575 indicate most likely recycled vitrinite as the sub-angular to mostly angular morphology with generally with clean surfaces suggest (Fig. 5). Presence of bimodal distribution of the mean vitrinite reflectance values was also reported in the 2016 Round Robin Exercise and thus, it cannot be explained by poor sample preparation. However, lower reflectance values at ≤ 0.400% VRr and higher reflecting values of the second vitrinite population at ≥ 0.575% VRr might be attributed to the inadequate sample preparation as reported by some participants. In the Fig. 4. individual histograms with reflectance values measured by participants are displayed. Most of the displayed values cover both vitrinite populations 1 and 2, however at a different proportion.

In Fig. 5. Some images of encountered vitrinite with random reflectance values are displayed.

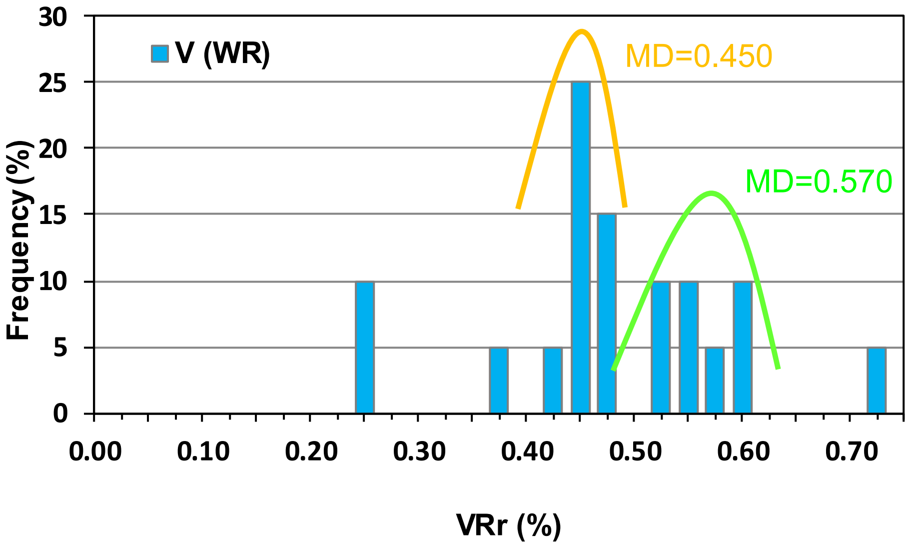

Fig. 2. Histogram constructed with the mean random vitrinite reflectance values provided by the participants for the whole rock sample; Class 0.025.

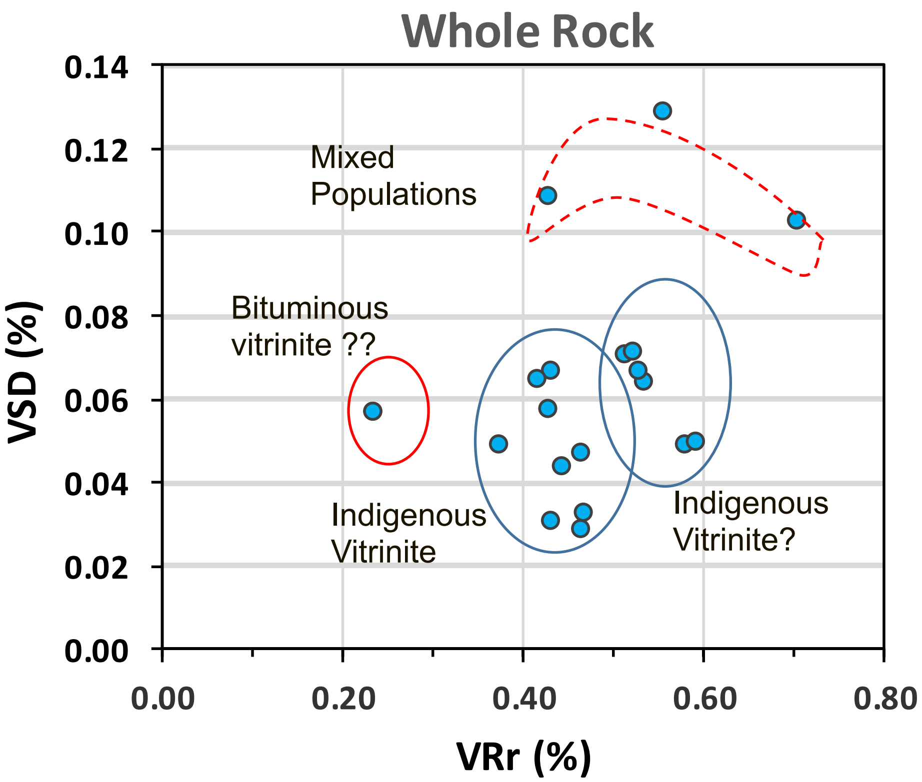

Fig. 3. Diagram showing the relationship between random vitrinite reflectance VRr (%) and standard deviation VSD (%) for a vitrinite reflectances measured in whole rock sample.

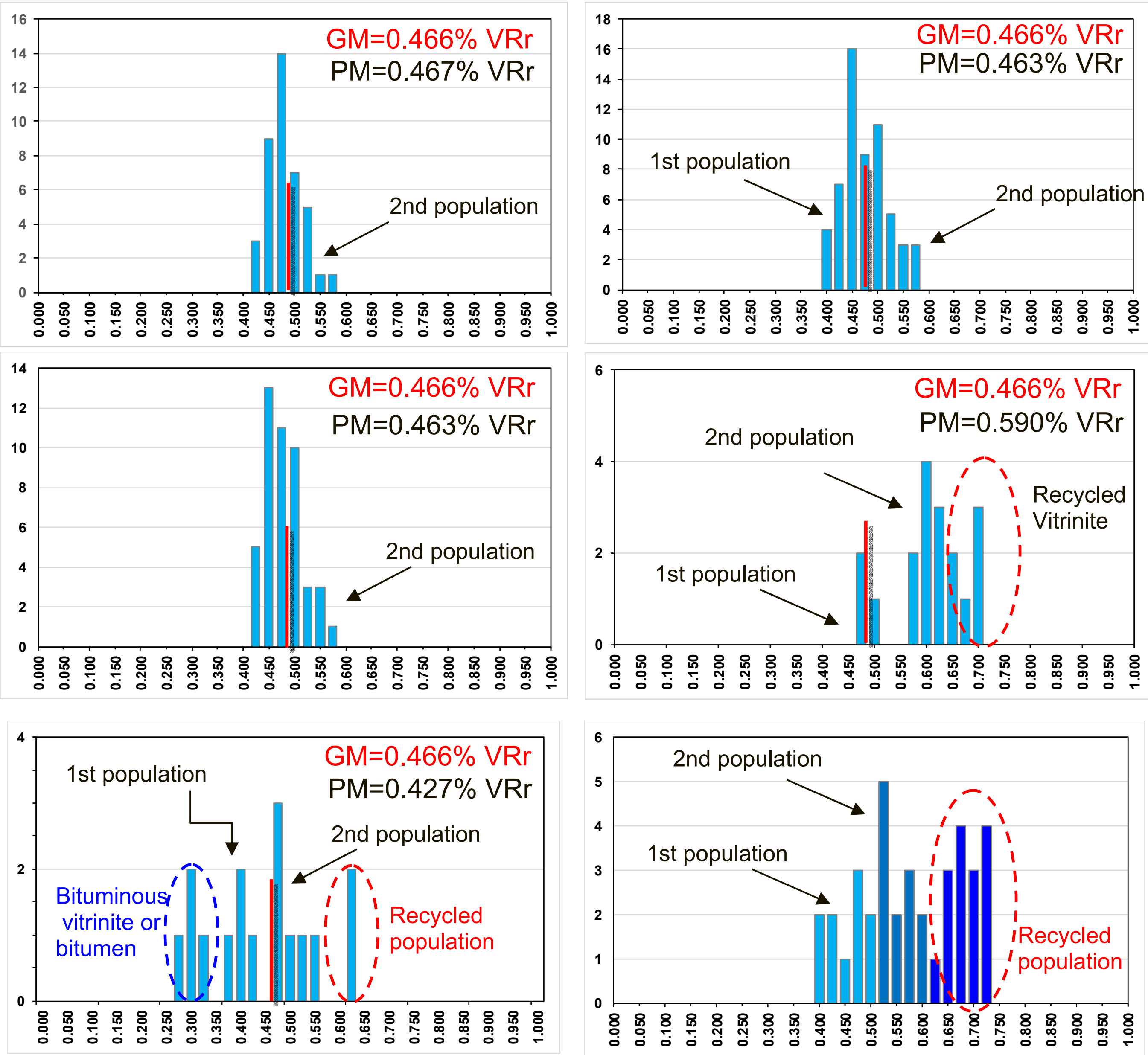

Fig. 4. Histograms (class 0.025) (pale and dark blue colors) of vitrinite particles in whole rock sample provided by participants and allocated to either the first or the second vitrinite population. Histogram (diverse blue colors; bottom right) of vitrinite particles as measured by the Convenor. Measurements of participants covered the first two populations. The third population (indigo) represents recycled vitrinite.

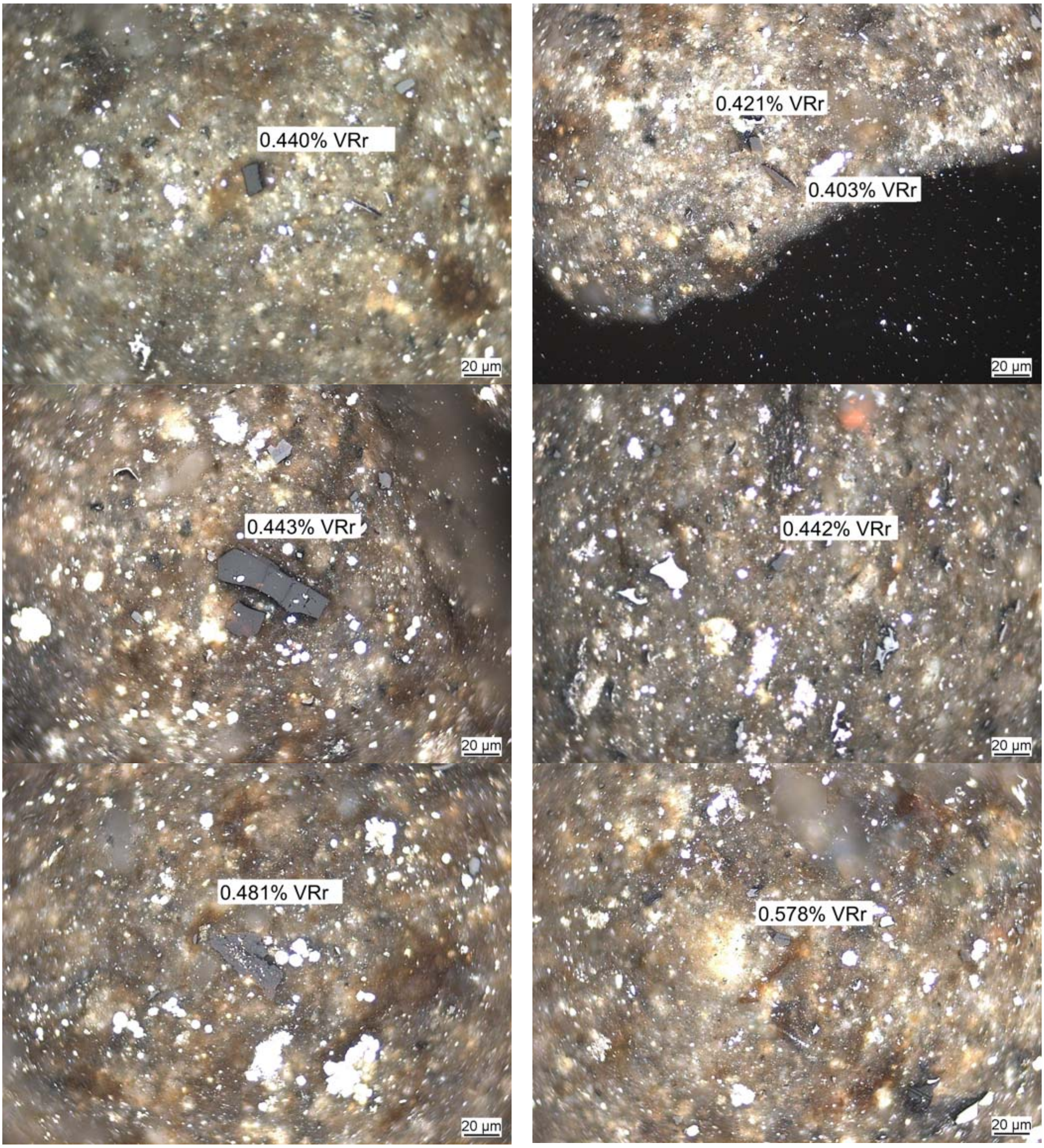

Fig. 5. Photomicrographs of vitrinite particles in whole rock sample allocated either to the first or the second vitrinite population. Magnification 500 ×; oil immersion objective.

Bituminite reflectance in whole rock

The measurements of random bituminite reflectance in whole rock sample were performed by 20 participants. The obtained reflectance values range from 0.09 to 0.28% BRr with a group mean reflectance value of 0.20% BRr (Fig. 6).

The variation in the measured values is relatively low as shown by the low group standard deviation of 0.044. This suggests that the participants did not have any difficulties in identifying bituminite in the whole rock sample. The separation of the provided bituminite reflectance values in relatively discrete populations is obvious with peaks at 0.188 and 0.250 % BRr and a class width of 0.025 (Fig. 7).

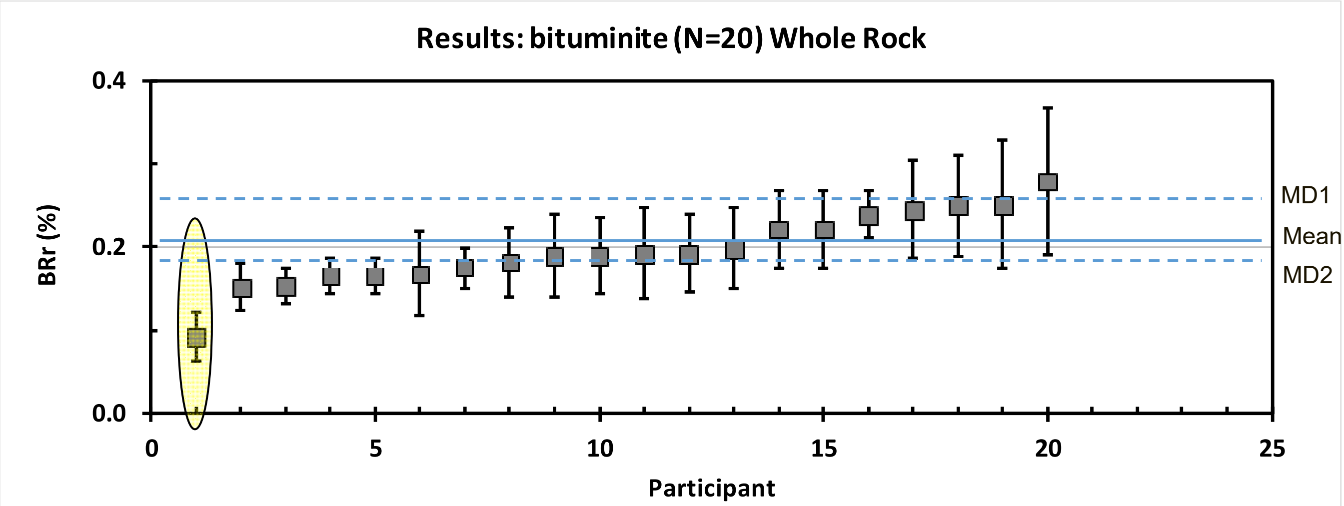

Fig. 6. Distribution and scatter of random bituminite reflectance values. The solid line correspond to the mean value and the dotted lines to the modal values. The value marked in yellow indicate an anomalously low reflectance value.

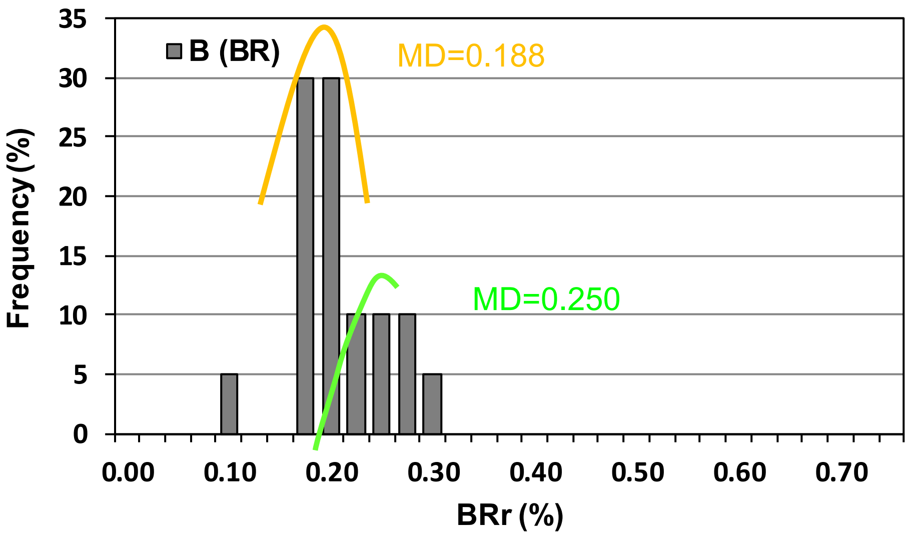

Fig. 7. Histogram constructed with the mean random bituminite reflectance values provided by the participants for the whole rock sample.

The cross plot between random bituminite reflectance (BRr %) and standard deviation (BSD) for whole rock are shown in Fig. 8. The diagram shows noticeably a bimodal distribution of the obtained reflectance values. Two data points marked in red are characterized by elevated standard deviation are interpreted as mixed populations. The remaining measured values are displayed as bimodal populations. Most participants measured, on average, 40 bituminite particles in the case of whole rock sample (Fig. 8).

In the Fig. 9. individual histograms with reflectance values measured by participants are displayed. Most of the displayed values cover both bituminite populations 1 and 2, however at a different proportion.

In Fig. 10. Some images of encountered bituminite with random reflectance values are displayed.

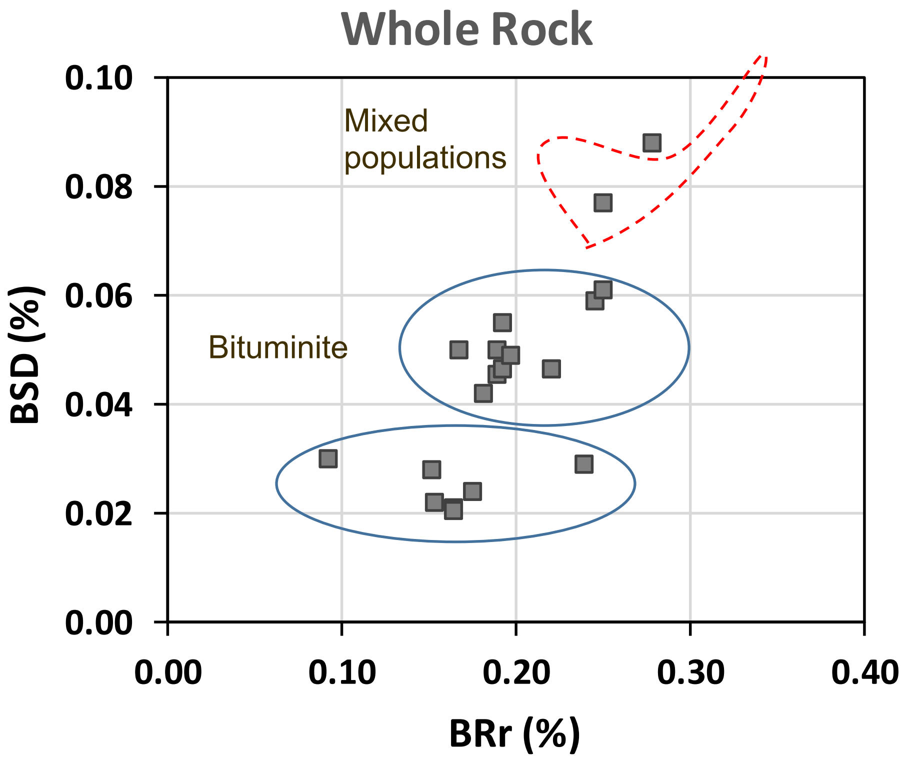

Fig. 8. Diagram showing the relationship between random bituminite reflectance BRr (%) and standard deviation BSD (%) for a bituminite reflectances measured in whole rock sample.

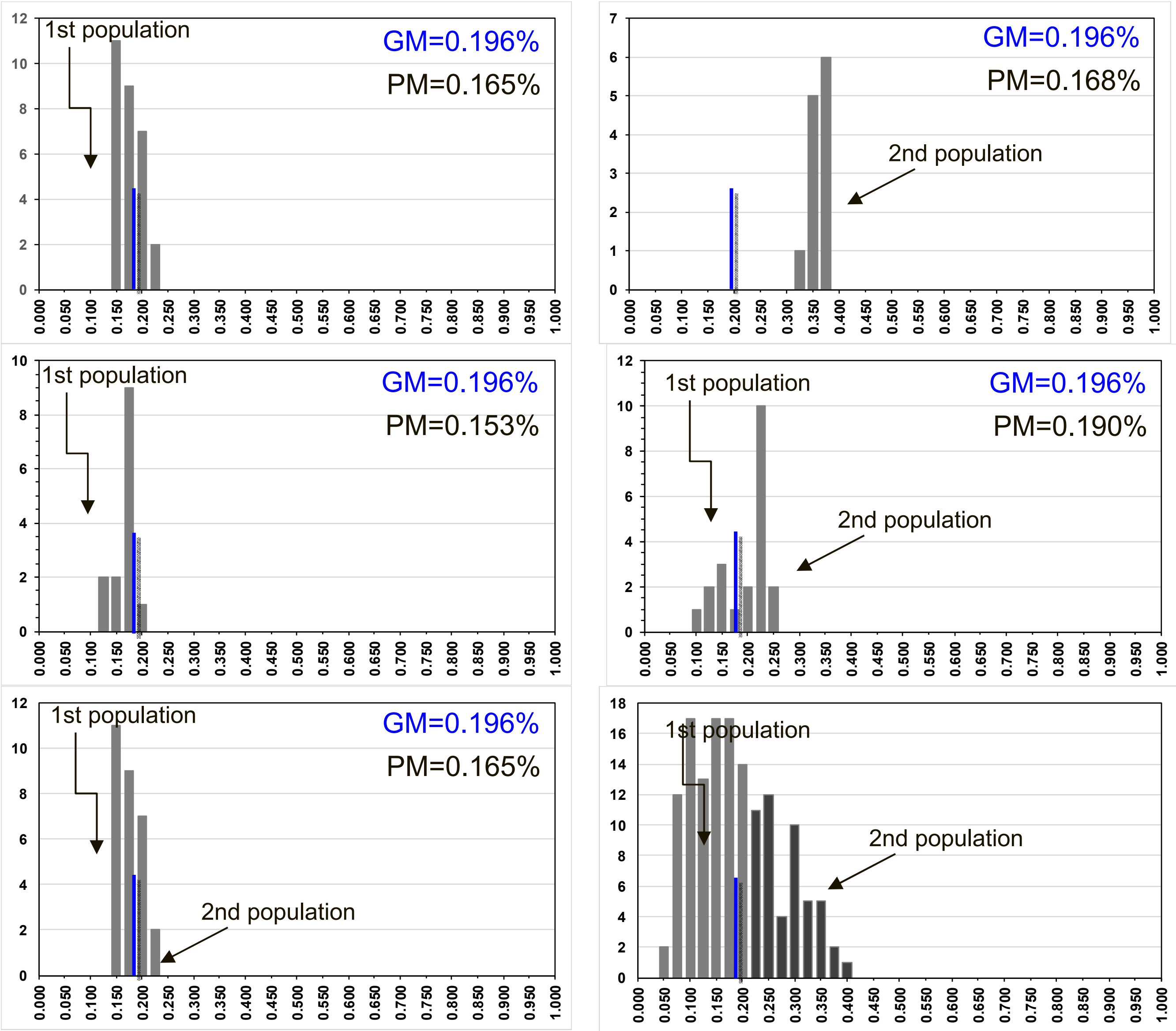

Fig. 9. Histograms (class 0.025) (pale and dark gray colors) of bituminite particles in whole rock sample provided by participants and allocated to either the first or the second bituminite population. Histogram (diverse gray colors; bottom right) of bituminite particles as measured by the Convenor. Measurements of participants covered the first and second populations or just the second population.

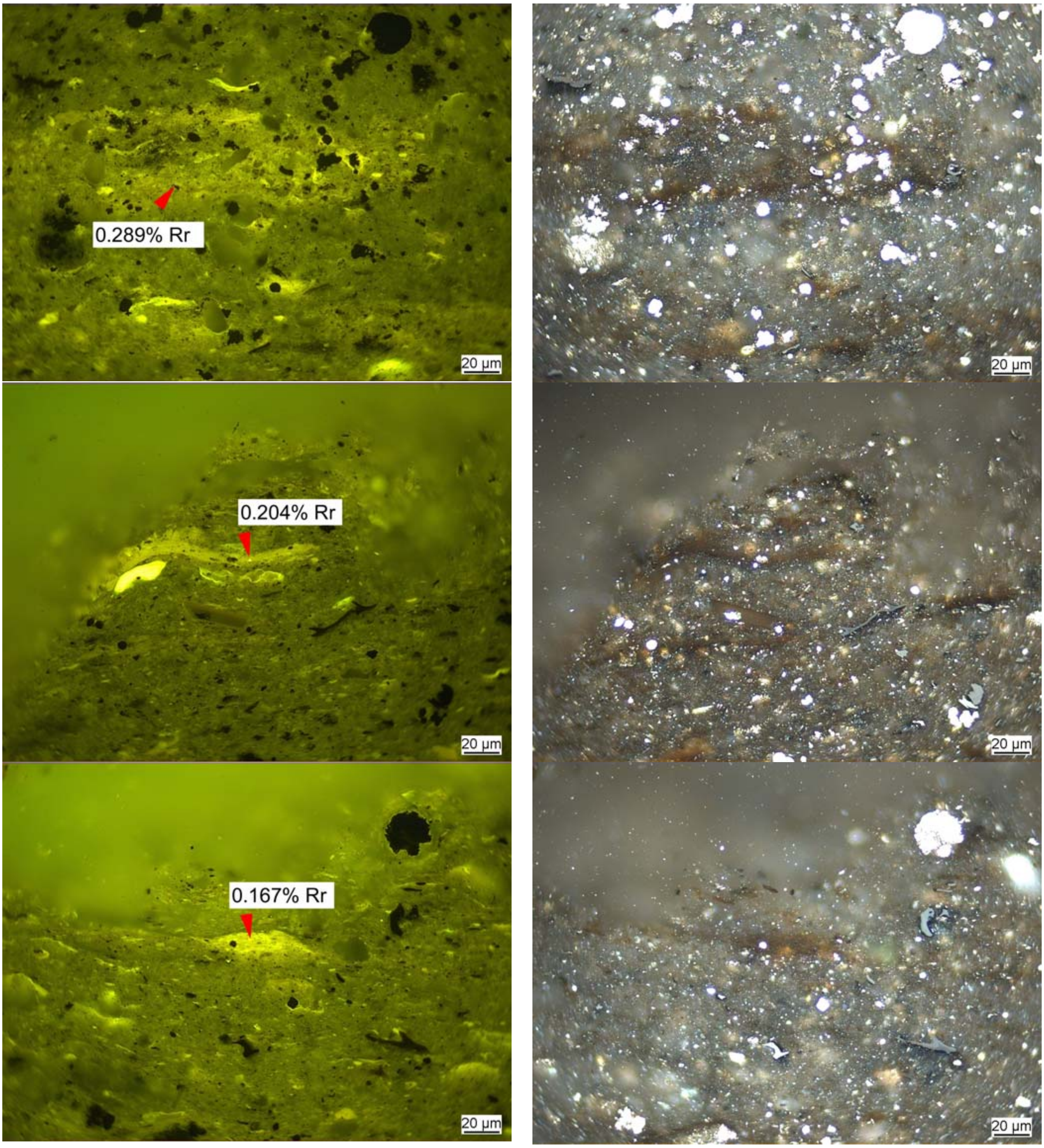

Fig. 10. Photomicrographs of bituminite particles in whole rock sample. Magnification 500 ×; oil immersion objective.

Description of bituminite macerals

Detailed comments:

I. **Form:**	Whole rock sample
1. laminae, irregular streaks, wisps, flaser, pods, thrads, bands and elongated lenses	**Irregular streaks** A organic maceral can only be considered bituminite if it has a distinguishable boundary even though the boundaries have irregular form. Some difficulty has been encountered because the boundaries visible in white light differentiating something darker and more compact from the matrix sometimes disappear under fluorescence showing a continuity between the matrix or groundmass and the potential bituminite. Elongated lenses, laminae Bituminite A and B – irregular streaks Bituminite A and B – irregular streaks Laminae, band and elongated lenses. Elongated lenses, less commonly streaks Irregular streaks> bands > elongated lenses > wisps Bituminite A: Mostly irregular streaks and short lenses. Bituminite B: threads and elongated lenses. Mainly filamentous laminae, streaks, and elongated lenses with minor wisps, band and pods. Irregular streaks, wisps, threads, laminae Mostly laminae and irregular streaks with rare elongated lenses and irregular bodies Bituminite A and Bituminite B – irregular streaks **Irregular streaks** Laminae, flaser, “schlieren” lenses, and treads mostly in clayey laminated lithotype; Irregular and wisps in the more granular grains. Mostly irregular streaks and short lenses (Bituminite A). Bituminite B shows mostly threads and elongated lenses.
2. others	Some bituminite grains are of irregular form Short bituminite laminae and points dispersed in clay matrix Clots, blots
II. Size:	
1. streak and thread forms are <2-200 µm long and <2-4 µm thick	**Streak and thread forms are <2-100 µm long <2-4 µm thick** X Bituminite A and B – sometimes thicker than the upper limit proposed Bituminite A and B – sometimes thicker than the upper limit proposed This is very abundant. Some lenses are longer than 200 µm and thicker <2-4 µm. Yes This is very abundant Bituminite A: < 200 µm long and < 2-10 µm thick; Some lenses are longer and thicker than 200 µm and 4 µm, respectively but mostly <100 µm <3-5µm thick and 20-30µm 60% Bituminite A and Bituminite B – Many different sizes. Sometimes thicker than the upper limit proposed. **Streak and thread forms are <2-100 µm long <2-4 µm thick** Laminae and streaks from 50->200µm and thickness between 2-10 µm Bituminite A: < 200 µm long and < 2-10 µm thick; Bituminite B: > 200 µm long and < 2-4 µm thick;

2. lenses, flaser and pods are <2-10 µm long and <2-4 µm thick	This is abundant. No, lenses are 50 µm and 5-10 µm thick Relatively common, possibly thinner particles Bituminite B: > 200 µm long and < 2-4 µm thick; Minor pods and lenses 70 x 100µm 40% Bituminite A: < 200 µm long and < 2-10 µm thick; Bituminite B: > 200 µm long and < 2-4 µm thick;
3. others	The only forms that could be distinguished as an individual component were thicker than 2-4 µm, otherwise would be not possible to distinguish them from the groundmass. It occurs similarly with length, only relatively large components over 20-25 µm Observed formations longer than 200µm 35 x 70µm (clots)
III. Appearance:	
1. vein-like appearance	**Vein-like appearance** And also elongated, which is less specific than vein-like Bituminite A and B Bituminite A and B This is abundant Relatively common irregular laminae and streaks Bituminite B: Mainly vein-like appearance and it occurs fine disseminated. Mainly vein-like appearance Marking the sedimentation surfaces Mostly Bituminite A and Bituminite B **Vein-like appearance** Mostly "laminated" parallel to the sedimentary lamination axis. Lenses also follow this parallel fabric. Occasionally vein-like or fine disseminated bituminite mostly in the non-laminated granular lithotype. Bituminite B: Mainly vein-like appearance and mostly fine disseminated.
2. fine disseminations	Fine disseminations should be avoided, because this could only be associated to the groundmass X Common This is abundant, also fine grains concentrated in irregular to longitudinal formations Minor component of fine disseminations In fine grained mixes with mineral material Some times Bituminite B: Mainly vein-like appearance and mostly fine disseminated. Mostly
3. homogenous, diffuse, equidimensional particles of various shape	The word particle should be avoided because sometimes the boundaries are not so clear as could correspond to a particle of a given component embedded in a matrix. Probably a better word is simply component Bituminite B Bituminite B Some homogenous with various shape and sizes Most common Some homogenous particles with various shape and sizes were observed. In general, some particles of Bituminite A have homogenous to diffuse appearance and equidimensional size, they are irregular streaks and short lenses in shape Some homogenous with various shape and sizes Very often Bituminite B

	Bituminite A is homogenous to diffuse and shows equidimensional particles of irregular streaks and short lenses.
4. others	X
IV. Impurities:	
1. lack of impurities	Normally it has impurities, although in some cases they are not observed. Without impurities, some can be easily mistaken as compact lenses of lamalginite maceral Mostly free of impurities Probably without impurities Bituminite B do not contain impurities Only trace amount Yes Commonly Bituminite B do not contain impurities Rare
2. minerals	**Pyrite (Framboidal and dispersed grains) and Carbonate** In the sample analysed I think this case is quite common, especially when the potential bituminite does not show fluorescence pyrite Bituminite A Bituminite A Pyrite yes Crystals and framboids of pyrite, clay minerals and quartz Bituminite A presents mineral impurities (mainly pyrite and carbonates). Framboidal pyrite/micrinite Adjacent minerals Occasionally – mostly pyrite Bituminite A (mainly pyrite) **Pyrite (Framboidal and dispersed grains) and Carbonate** Clays, pyrite, other silicates and carbonates. It was observed mineral impurities (mainly pyrite and carbonates in Bituminite A. Frequent
3. corroded algal remnants	Present, even uncorroded, not only corroded alginite X Bituminite B Bituminite B Yes Yes, mainly dinoflagellate cysts and acritarchs It was observed Yes Yes Bituminite B Observed
4. liptodetrinite	**Liptodetrinite present** Present frequently X Bituminite B Bituminite B Yes, very common This is very common Bituminite A is associated with liptodetrinite Yes, and some small, fluorescing prasinophyte alginite Yes Rarely Bituminite B

	Liptodetrinite present Observed Occasionally Bituminite A is associated with liptodetrinite Some
5. others	**Microspores frequently recorded in the** Bituminite B – sporinite B Bituminite B – sporinite Sporinite, alginite, inertodetrinite fragments micrinite Residues of other liptinite macerals may occur. Occurrence of vitrinite and inertinite macerals Some whole alginite Sporinite in Bituminite B
V. Internal structure	
1. homogenous	In white light is not frequently homogeneous X Bituminite A – Homogeneous to streaky Bituminite B Bituminite A – Homogeneous to streaky Bituminite B Some particles Homogenous structure was sparsely observed Bituminite A and B are both mostly homogenous Some particles but not all As initial, not transformed maceral X The types of bituminite A and B are mainly homogenous Very few
2. streaky	**Streaky** Yes This is common Yes With thin mineral matter, often Occasionally **Streaky** X Some
3. fluidal	Few I can not it imagin, too abstract Very rare Already transformed to “Bitum” -secondary product X
4. finely granular	In white light is frequently granular X Yes, very common Most common Common in bands, lenses and irregular forms Major amount of granular bituminite As a result of porosity accompanying transformation Mostly X mostly Mostly
5. others	Massive bodies of various shape and size
VI. Optical properties – white light	All, depending on the maturity

1. pale grey	Rare No As rims of the initial macerals during "oil window" Pale-brown to brown to dark grey I would go grey, mostly, if pale or dark would be a matter of the illumination. They are less pale (bright, than the vitrinite particles
2. dark grey	X Bituminite A Bituminite A Minor dark grey bituminite Most common Dark grey with occasional with internal colour reflexes Bituminite A is dark grey Mostly dark grey bituminite Before "oil window" Mostly Bituminite A Bituminite A is dark grey See above
3. black	Minor black bituminite Some cases Rare black particles If it black in white light then you cannot see it.
4. others	**Dark brown to Black** In the sample analysed also brownish with reddish internal reflections Dark brown Bituminite B – grey (translucent) Bituminite B – grey (translucent) Common brown to dark brown bituminite with partly reddish reflexes Bituminite B is brownish translucent minor brown to very dark brown Brownish during "oil window" Bituminite B – grey (translucent) **Dark brown to Black** Bituminite B is brownish translucent
VII. Optical properties – UV light	All, depending on the maturity
1. greenish	Rare Rare, probably algae remnants Very rare Yes X
2. yellowish	**Yellowish** Bituminite B - intense yellow Bituminite B - intense yellow Yes, most common Most common Bituminite B is yellowish Some weak yellow to yellow-orange fluorescence Yes XXX Bituminite B - intense yellow **Yellowish** X Bituminite B is yellowish Yellowish

3. reddish	Trace amount Rare Minor reddish-orange Yes X
4. brownish	X Bituminite A – dark orange to brown Bituminite A – dark orange to brown Yes, most common Yes Sometimes, also the colour brownish-yellow Bituminite A is brownish Mostly reddish-brown Yes XXXXX **X** Fluorescence colour: Bituminite A is brownish Yellowish to light brownish
5. others	In the sample analysed also lacking fluorescence sometimes. Non-fluorescent Vitrinite weak brown Bituminite A – dark orange to brown
VIII. Association with	
1. Bituminit I of Teichmüller and Ottenjann (1977)	**Bituminite I (Fluorescing yellowish to orange)** Bituminite A and B Bituminite A and B Mostly associated to this description A smaller part of the bituminite corresponds to this description Both types of bituminite were considered to be Bituminite I of Teichmüller and Ottenjann (1977) Mostly associated to this description Bituminite A and Bituminite B **Bituminite I (Fluorescing yellowish to orange)**
	Mostly observed Bituminite I and III. Bituminite II subordinately, or associated with algae. In many occasions intermixed with fine mineral matter.
	Both types of bituminite fits well into Bituminit I of Teichmüller and Ottenjann (1977)
2. Bituminit II of (Teichmüller and Ottenjann (1977)	Common A significant part of the bituminite corresponds to this description Minor amount of bacterial degradation Mainly
3. Bituminit III of Teichmüller and Ottenjann (1977)	Traces Sporadic occurrence Traces of bituminite III, possibly from phosphatic fish bones.
4. Bituminit I of Mackenzie-Basin (Creaney, 1980)	Partly associated to this description Mostly associated to this description
	Trace
5. Bituminit II of Mackenzie-	Partly associated to this description

Basin (Creaney, 1980)	
6. amorphinite A, of van Gijzel, 1980	Partly associated to this description
7. amorphinites B of van Gijzel, 1980	Partly associated to this description = bituminite II
8. amorphinites C of van Gijzel, 1980	Sporadic occurrence, probably fecal pellets
9. sapropelinites I of Mukhopadhyay et al. (1985 a,b).	Mostly associated to this description Some association to this description
10. sapropelinites II of Mukhopadhyay et al. (1985 a,b).	X Sporadic occurrence
11. others	Yes (Fluoamorphinite, Senftle et al., 1987) Tempted to call some areas mineral bituminous groundmass
IX. Others	
1. Comments, remarks	**The microspores occur frequently; Framboidal pyrite also observed;** I encountered big difficulties to analyse the sample when polished under water using standard preparation techniques. Very few particles were suitable to take a measurement and even in these cases it was not clear whether the particle was totally horizontal or inclined due to the lack of coherence with the mineral matrix. A second attempt was done to polish the sample with polishing oil and cleaning it with alcohol at the end. This procedure has typically a less perfect ending for the surface but reduce the problems of incoherence with the minerals. Many more particles were available for polishing in this case. Identification complicated (bitumite – dark vitrinite, algae?) Two bituminite types were identified and are referred to as Bituminite A and Bituminite B. Bituminite A is translucent and displays darker colour in RWL, and is dark orange to brownish in incident blue light. This bituminite exhibits the presence of impurities, namely mineral. Bituminite B is also translucent but exhibiting lighter features, and displays an intense yellow fluorescence colour. This bituminite presents impurities, such as, liptodetrinite, alginite and sporinite. It is not clear to me whether these columns are intended to be used as I used them or intended to be filled with relative proportions in vol% of the different types The breakdown of bituminite is complicated and very detailed. Problems with its characterization and classification are heavily dependent on the magnification used. It was observed presence of *Tasmanites* and dynocists (basal view), lamalginite yellow fluorescence colour and sporinites. Some difficulties were encountered in the process of assembling the polished section, mainly that related to the polishing process, since the organic material is very dense. Bituminite occurred as elongated lenses or some cases rounded pods, with brownish-grey or reddish-brown patches of homogenous diffuse appearance in white light. Compare to the previous exercise with a lower maturity

sample in 2017 the "outline of bituminite" was more visible. For the reflectance measurement the distinguishing of the amorphous organic matter bituminite from the rock matrix was easier. Bituminite had no fluorescence in blue or ultra violet excitation. Bituminite contained some times framboidal pyrite crystals as inclusions but more frequently micrinite or micrinite like bright sparkling dots were visible on the surface especially when the diaphragm blend was used to reduce the illuminated surface of the surrounding the measuring point. In the full field illumination only pyrite impurities were visible. With the diaphragm the bituminite surface of the lighted ring was dark grey or black and the surface was not smooth and reflecting but rather finely granular and the micrinite dots appeared regularly in it.

Bituminite bodies are mostly translucent and occur as thin laminae

Bituminite is abundant and it occurs in a variety of morphologies but generally present as irregular streaks. Bituminite grades to mineral bituminous groundmass, which is faint reddish in color (in white light) and identified as less dense concentrations of organic matter than are present in the bituminite schlieren and streaks. Qualitatively, bituminite may occur with greater concentrations of pyrite than in the bulk rock. Morphologies of bituminite include irregular streaks, laminae, wisps, pods, disseminations, and rare equidimensional occurrences. Generally, bituminite occurs in morphologies thicker than 2-4 μm, usually 5-10 μm thick and 30-50 μm in long dimension. Some more laminated varieties are present that are >50 μm in length. The terms 'vein' and 'thread' are judged to be poor descriptors of bituminite in this sample. In some places bituminite is homogeneous but more likely the occurrences are inhomogeneous with granularity, containing pyrite and clay(?) inclusions, corroded algal remnants, micrinite (bright granular component, whether organic or inorganic) or other liptodetrinite fragments. Fluidal textures are not present. In white light bituminite is frequently reddish and translucent and sometimes with a pale to dark gray, and black, reflecting surface. In blue light bituminite is yellowish to brown to non-fluorescent. In my opinion, the previous division of bituminite and equivalents (amorphinite, sapropelinite) into multiple sub-macerals (Creaney, 1980; Mukhopadhyay et al., 1985; Teichmüller and Ottenjann, 1977; Van Gijzel, 1982) is unhelpful because these terms cannot be applied in a reproducible way (that is not to say the cited studies have no other merit). That is, I predict an interlaboratory study would show that one petrographer's 'bituminite I' is another petrographer's 'bituminite II' and yet another petrographer's 'bituminite III'. The incorporation of multiple useless terms into the literature is confusing and only obfuscates the communication of the science. Therefore, my recommendation is to use only the term 'bituminite' with the understanding that it represents a continuum with multiple other macerals, including: solid bitumen, mineral bituminous groundmass and alginite as described in Hackley et al. (2018). Of course, it is fair to then describe 'bituminite' to as much detail as one wants.

Two different types of bituminite were identified, Bituminite A and Bituminite B. These two types of bituminite present different optical properties, as reported in the following table. The Bituminite A is darker translucent in RWL and present a dark orange to brown colour under incident blue light. The Bituminite B is also translucent but lighter, and exhibit an intense yellow fluorescence colour. By the fact that the bituminite B is translucent lighter, its reflectance has not been measured. Presence of impurities in Bituminite A (minerals) and Bituminite B (alginite and sporinite).

According to microscope analysis, the Liptinite Group is very common. For exemple: *Tasmanites,* dynocists (basal view), lamalginite with yellow fluorescence colour and sporinites

Great exercise, great sample. Wished I had had the Rock Eval data a t the beginning. Thank you.

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