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Source rock evaluation and predicted petroleum compositions related to samples from the Adavale, Bowen, Cooper and Eromanga Basins, Queensland

Interim Report 3

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Introduction

The Department of Natural Resources and Mines (DNRM) of the Geological Survey of Queensland (GSQ) contracted GEOS4 to evaluate the petroleum geochemical characteristics of 48 samples from the Cooper, Eromanga, Bowen and Adavale basins of Queensland. GSQ provided the following background information:

Adavale Basin

The Adavale Basin is an under-explored basin in southern-central Queensland. Exploration in the 1960s resulted in the discovery of the Gilmore gas field, though no other discoveries have been made. The presence of the Gilmore gas field demonstrates a proven petroleum system.

Cooper Basin

The Cooper Basin forms part of one of Queensland's major petroluem provinces, and hosts several conventional oil and gas fields. There has also been recent exploration for unconventional gas resources in the deeper troughs of the basin. Knowledge of the generative capacity of the potential source rocks in this basin will give a better understanding of this unconventional gas potential.

Eromanga Basin

The Eromanga Basin overlies the Cooper Basin and is the other component of the Cooper-Eromanga petroleum province in south-west Queensland. Discoveries in the Eromanga Basin have been predominantly oil, and include the Jackson field, which is Australia's largest onshore oil field. The source for these fields is thought to be predominantly from source rocks in the Cooper Basin, though up to 25% may have been from source rocks within the Eromanga Basin itself.

Bowen Basin

The Bowen Basin forms part of the other major petroleum province in Queensland and is believed to host the principal source rocks for the Bowen and Surat basins conventional accumulations. Conventional reserves were first discovered in the basin in the 1960s, though recent development in the area has focussed on coal seam gas resources underpinning the world class CSG to LNG industry. Recent exploration has targetted deeper sections of the Taroom Trough for tight gas resources with a significant potential for additional unconventional resources such as deep shales and coals yet to be discovered.

Objectives

Our objective is to provide the GSQ and the petroleum industry with a better understanding of the petroleum systems and the petroleum resource potential within these basins through provision of pre-competitive data. There are two principal foci: compositional kinetics for potential sources in the Bowen and Eromanga Basins, and deep gas generation in the Cooper and Ardvale Basins.

Aim of this part of the study

To conduct a semiquantitative maceral analysis of seven coals and four shales and make vitrinite reflectance measurements.

Samples and Methods

In accordance with the work plan laid out in GEOS4 Report 20161016 the following samples were selected for organic petrological analysis:

Basin	Code	QLD i.d.	Rock Type	Rock Unit Name	Petrology
COOPER BASIN	G016496	GSV03	Coal	Patchawarra Formation	1
COOPER BASIN	G016500	GSV07	Coal	Toolachee Formation	1
EROMANGA BASIN	G016504	GSV11	Carb'ceous mst	Birkhead Formation	1
EROMANGA BASIN	G016505	GSV12	Coal	Birkhead Formation	1
BOWEN BASIN	G016511	GSV18	shale	Bandanna Formation	1
BOWEN BASIN	G016513	GSV20	shale	Black Alley Shale	1
BOWEN BASIN	G016522	GSV29	Coal	Aldebaran Sandstone	1
BOWEN BASIN	G016524	GSV34	shale	Snake Creek Mudstone Mbr	1
BOWEN BASIN	G016531	GSV40	Coal	Tinowon Sandstone	1
BOWEN BASIN	G016535	GSV45	Coal	Riverstone Sst Mr?-Cattle Creek Formation	1
BOWEN BASIN	G016539	GSV49	Coal	Reids Dome beds	1
				RUNNING TOTALS	**11**

For optical microscopy on coal and shale samples, blocks were cut, embedded into epoxy resin and polished, to obtain a smooth surface. Mean random reflectance (%Rr, oil immersion) was determined using a Leica MPV microscope equipped with 50x and 100x objectives at a wavelength of 546 nm. The 50x magnification was used for coals, while shale samples were investigated using the 100x magnification.

Maceral composition was assessed qualitatively and semi-quantitatively using white-light and blue-light irradiation. The fluorescence color of liptinite macerals was used as a quality parameter for reassurance of measured vitrinite reflectance values.

The maceral abundance and vitrinite reflectance data are found in Tables 1 and 2.

Results

G016496:

Organic matter (Fig. G016496): The coal sample is dominated by vitrinite (mainly collodetrinite; 63 %), followed by semi-inertinite (23 %), which is part of the inertinte maceral group, and inertinite (mostly pyrofusinite; 6 %). Liptinite (mainly sporinite) is less abundant. Mineral matter shows a weak fluorescence colour under blue light irradiation. Sporinite shows a very weak orange fluorescence colour under blue light irradiation. Cutinites mainly do not show fluorescence anymore.

Vitrinite reflectance: Vitrinite reflectance was measured on large, homogeneous and strongly gelified particles (collotelinite) and a mean value of 0.88 %Rr was obtained. However, only weak to absent fluorescence of cutinite macerals might even point to a slightly higher maturity in the range of 0.90 - 0.95 %Rr.

G016500:

Organic matter (Fig. G016500): This coal sample is dominated by vitrinite (83 %). Vitrinite macerals consist mainly of collodetrinite and collotelinite in lower amounts. Semi-inertinit and inertinite occur in low amounts (14 % in sum). Sporinite is the main liptinite maceral within this sample, while cutinite is very rare. Mineral matter is also very rare (very low ash content of the coal). A low amount of pyrite is visible in the polished block.

Vitrinite reflectance: An average vitrinite reflectance of 0.72 %Rr was obtained for this sample. The measured reflectance is in good agreement with the observed strong orange fluorescence of sporinite.

G016504:

Organic matter (Fig. G016504): Organic matter (OM) in the shale sample is dominated by vitrinite (35 % of OM), alginite (35 % of OM) and sporinite (27 % of OM) in similar amounts. However, the observations on the polished block do not fully support the high HI of ~ 700 mgHC/gTOC. Inertinite is rare. Thin brown bands of OM occur within the sample. Vitrinite and inertinite particles are often very small (~20-50 µm). Alginite often shows a bright orange-yellow fluorescence color under blue light irradiation whereas sporinite is characterized by a yellowish/orange fluorescence colour.

Vitrinite reflectance: Several populations of vitrinite with slightly differing reflectivity exist in this sample. Reflectance measurements were performed on isolated vitrinite particles and yielded an average value of 0.53 %Rr. This is in good agreement with the bright yellowish to orange fluorescence of sporinite, as well as a bright orange fluorescence of cutinite.

G016505:

Organic matter (Fig. G016505): The coal sample is dominated by vitrinite (mainly collodetrinite; 89 %). Phlobaphinite, which is also part of the vitrinite maceral group, occurs within the collodetrinite groundmass. Liptinite (11 %) is visible in lower amounts. Sporinite is the most common maceral of the liptinite group. Rare cutinite occurs within the coal sample. Based on the shape and fluorescence colour under blue light irradiation, some liptinite particles were identified as resinite (see Fig. G016505). Sporinite shows a yellowish-orange fluorescence colour under blue light irradiation.

Vitrinite reflectance: The yellowish to orange fluorescence of sporinite and a slight background reflectance indicate rather low (early oil window) maturity. The measured vitrinite reflectance, obtained mainly from phlobaphinite particles within larger collodetrinites, averages at 0.48 %Rr, which is in good agreement with the fluorescence of liptinites.

G016511:

Organic matter (Fig. G016511): Vitrinite (collodetrinite) is the dominant maceral group (56 %) followed by semi-inertinite (20 %). Sporinite (5 %) and alginite (4 %) are the main macerals of the liptinite group. Inertinite is rare (4 %). Mineral matter is in the range of 11 %. Alginite shows an orange fluorescence colour under blue light irradiation, sporinite exhibits a yellow fluorescence colour.

Vitrinite reflectance: The measured vitrinite reflectance in this sample averages at 0.40 %Rr. This is in good agreement with a yellow fluorescence of sporinite and generally strong background fluorescence.

G016513:

Organic matter (Fig. G016513): OM in the shale sample is dominated by vitrinite (40 % of OM), followed by semi-inertinite (20 % of OM). Inertinite is rare (12 % of OM) but more abundant than sporinite (8 % of OM), which is the dominant maceral of the liptinite group. Alginite is very rare (below 1 % of OM). However, the considerable amount of liptinite in this sample does not support the very low HI (47 mgHC/gTOC) at the given maturity level. Particles of OM are usually small (< 40 µm) except some bigger, elongated vitrinites and semi-inertinite grains. Sporinite shows a yellowish/orange fluorescence colour.

Vitrinite reflectance: Two populations of vitrinite with slightly differing reflectivity were found. Measurements were conducted on larger elongated vitrinite particles, rather than on isolated small grains. The measured reflectance averages at 0.63 %Rr, which agrees with a yellowish-orange fluorescence of sporinite and alginite.

G016522:

Organic matter (Fig. G016522): The coal sample is dominated by vitrinite (42 %). Semi-inertinite is abundant (22 %). Sporinite is the main maceral of the liptinite group and occur frequently (13 %). Inertinite and alginite are rare (< 5 %). The mineral matter content is elevated (18 %) in comparison to the other coal samples. Sporinite shows a yellowish/orange fluorescence colour under blue light irradiation.

Vitrinite reflectance: Two populations of vitrinites exist within this sample. The darker population has a reflectance <0.4 %Rr. However, a yellowish to orange fluorescence of spores supports a slightly higher vitrinite reflectance. Therefore, the average reflectance of the relatively brighter vitrinite population (0.41 %Rr) was adopted. This value is still slightly lower than expected, considering the given fluorescence colour.

G016524:

Organic matter (Fig. G016524): OM in the shale sample is dominated by vitrinite (70 % of OM), followed by semi-inertinite (13 % of OM) and sporinite (10 % of OM). Inertinite and cutinite are rare (3 % of OM). Lamalginite occurs in very low amounts. Semi-inertinite particles are usually big (> 100 µm). Sporinite and cutinite show an orange fluorescence colour under blue light irradiation.

Vitrinite reflectance: Vitrinite macerals occur as relatively large bands, dominating over small, isolated particles. The reflectance along this layers is comparably uniform, an average random reflectance of 0.59 %Rr was obtained, which is in good agreement with the orange fluorescence of sporinite, as well as a bright orange to slightly brownish fluorescence of (rare) lamalginite.

G016531:

Organic matter (Fig. G016531): The coal sample is dominated by vitrinite (collodetrinite; 37 %). Semi-inertinite is abundant (29 %) and inertinite is common (13 %). Sporinite is the main maceral of the liptinite group and occur in low amounts (3 %). Mineral matter content is elevated (14 %). This mineral ground mass show a weak fluorescence colour under blue light irradiation. Sporinite shows a orange fluorescence colour under blue light irradiation.

Vitrinite reflectance: Vitrinite macerals within this sample show a relatively variable reflectivity with different sub-populations (partly < 0.5 %Rr). A clear orange fluorescence of sporinite argues for a vitrinite reflectance higher than the values obtainable from the relatively darker vitrinite populations, therefore, the most frequently occurring, relatively brighter population of vitrinites was measured. A mean random reflectance of 0.63 %Rr was obtained, which is generally supported by the fluorescence colors of liptinites, although the orange fluorescence of sporinites (as well as the Tmax of 439 °C) might even point to a slightly higher maturity.

G016535:

Organic matter (Fig. G016535): Vitrinite (collodetrinite; 67 %) is the dominant maceral group in the coal. Phlobaphinite which is part of the vitrinite maceral group, occur within the collodetrinite groundmass. Semi-inertinite and inertinite occur in similar amounts (10 %, 7 %, respectively). Sporinite and cutinite is common. Based on the strong fluorescence colour and the shape several particles were identified as fluorinite (see Fig. G016535). Alginite, resinite and pyrite are very rare. Sporinite shows an orange fluorescence colour under blue light irradiation.

Vitrinite reflectance: A mean vitrinite reflectance of 0.56 %Rr was obtained for this sample. This value is supported by the fluorescence colors of liptinites, as well as by the Tmax of 432 °C.

G016539:

Organic matter (Fig. G016539): OM in the shale sample is dominated by bands of vitrinite (80 % of OM). The sample is slightly laminated. Semi-inertinite, inertinite and sporinite occur in similar amounts (~6 % of OM). The mineral ground mass show a weak fluorescence color under blue light irradiation. Sporinite shows a yellowish/orange fluorescence colour under blue light irradiation.

Vitrinite reflectance: A mean vitrinite reflectance of 0.59 %Rr was determined for this sample, which is in good agreement with the yellowish to slightly orange fluorescence of sporinite macerals, a relatively strong background fluorescence, as well as a Tmax of 437 °C.

Table 1: Results of semi-quantitative maceral analysis

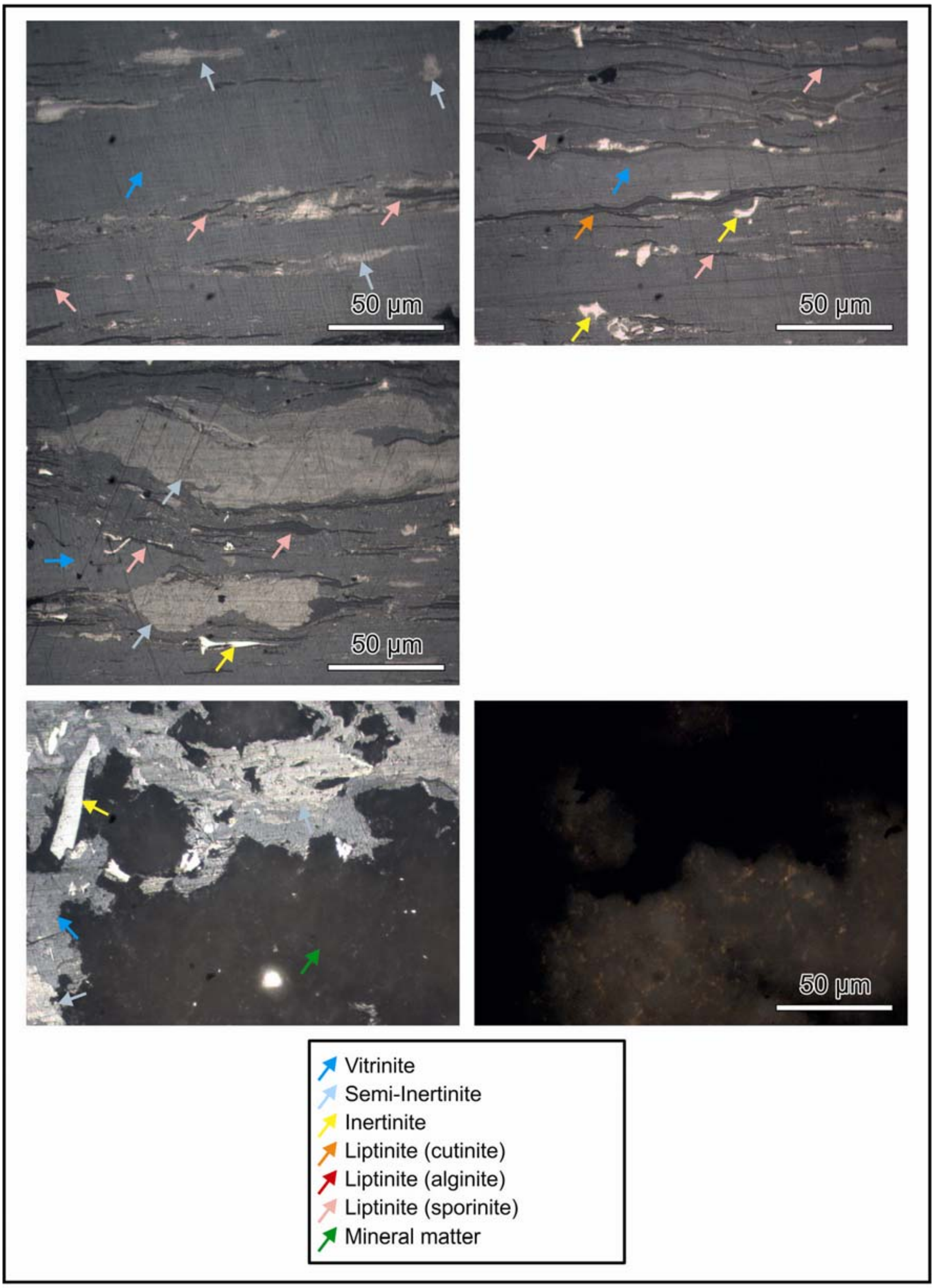
				Liptinite					
Coal samples	Vitrinite	Semi-Inertinite	Inertinite	Sporinite	Cutinite	Alginite	Fluorinite/ Resinite	Mineral matter	Comments
G016496	63	23	6	3	1			6	
G016500	83	8	6	4					Cutinite and pyrite are visible
G016505	89			8	2		1		6 % Phlobaphenite within Vitrinte
G016511	56	20	4	5		4		11	
G016522	42	22	4	13		1		18	
G016531	37	29	16	3			1	14	fluorescing ground mass; Cutinite is visible
G016535	67	10	7	4	2	1	1	8	3 % Phlobaphenite within Vitrinte; pyrite

Shale samples	Vitrinite	Semi-Inertinite	Inertinite	Sporinite	Cutinite	Alginite
G016504	35		3	27		35
G016513	40	40	12	8		
G016524	70	13	3	10	3	
G016539	80	8	6	6		

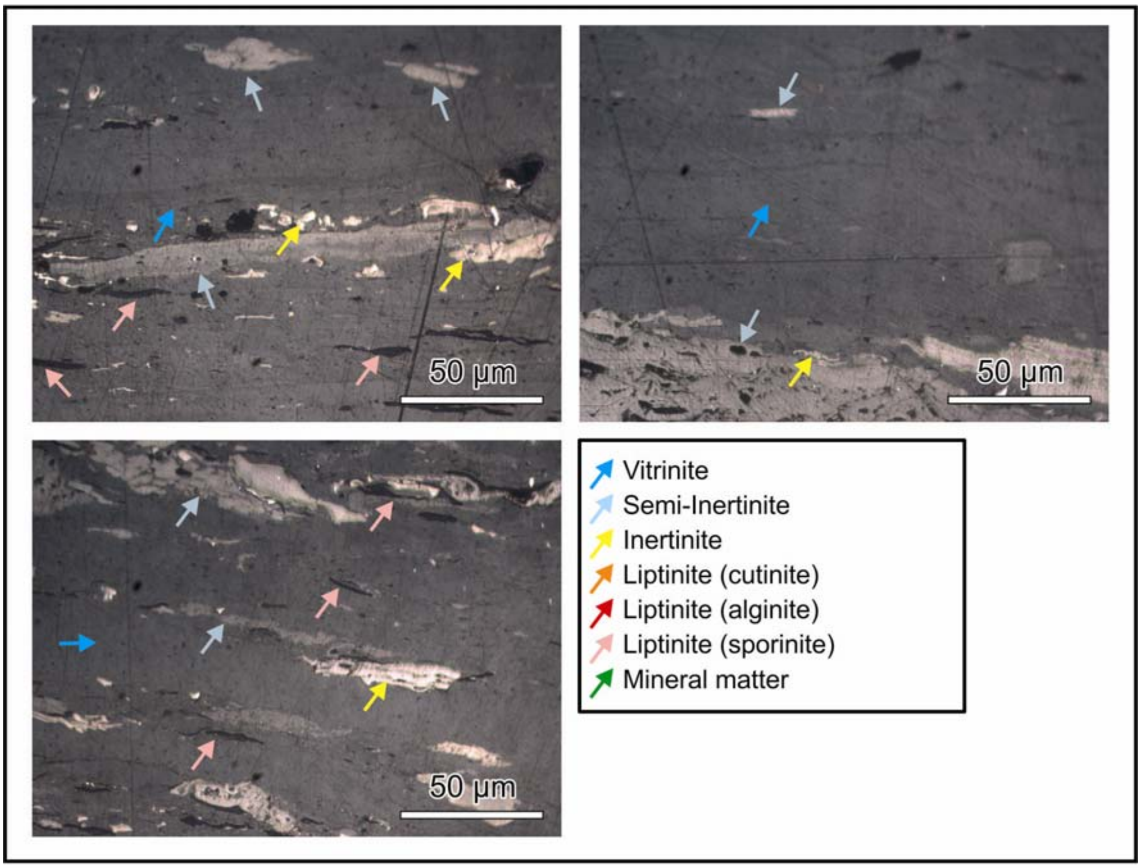
Table 2: Results of vitrinite reflectance measurements

Sample	Rr [%]	s	n
coals			
G016496	0.88	0.02	30
G016500	0.72	0.02	30
G016505	0.48	0.02	30
G016511	0.40	0.01	30
G016522	0.41	0.02	30
G016531	0.63	0.02	20
G016535	0.56	0.03	30
shales			
G016504	0.53	0.02	20
G016513	0.63	0.02	30
G016524	0.59	0.02	30
G016539	0.59	0.03	30

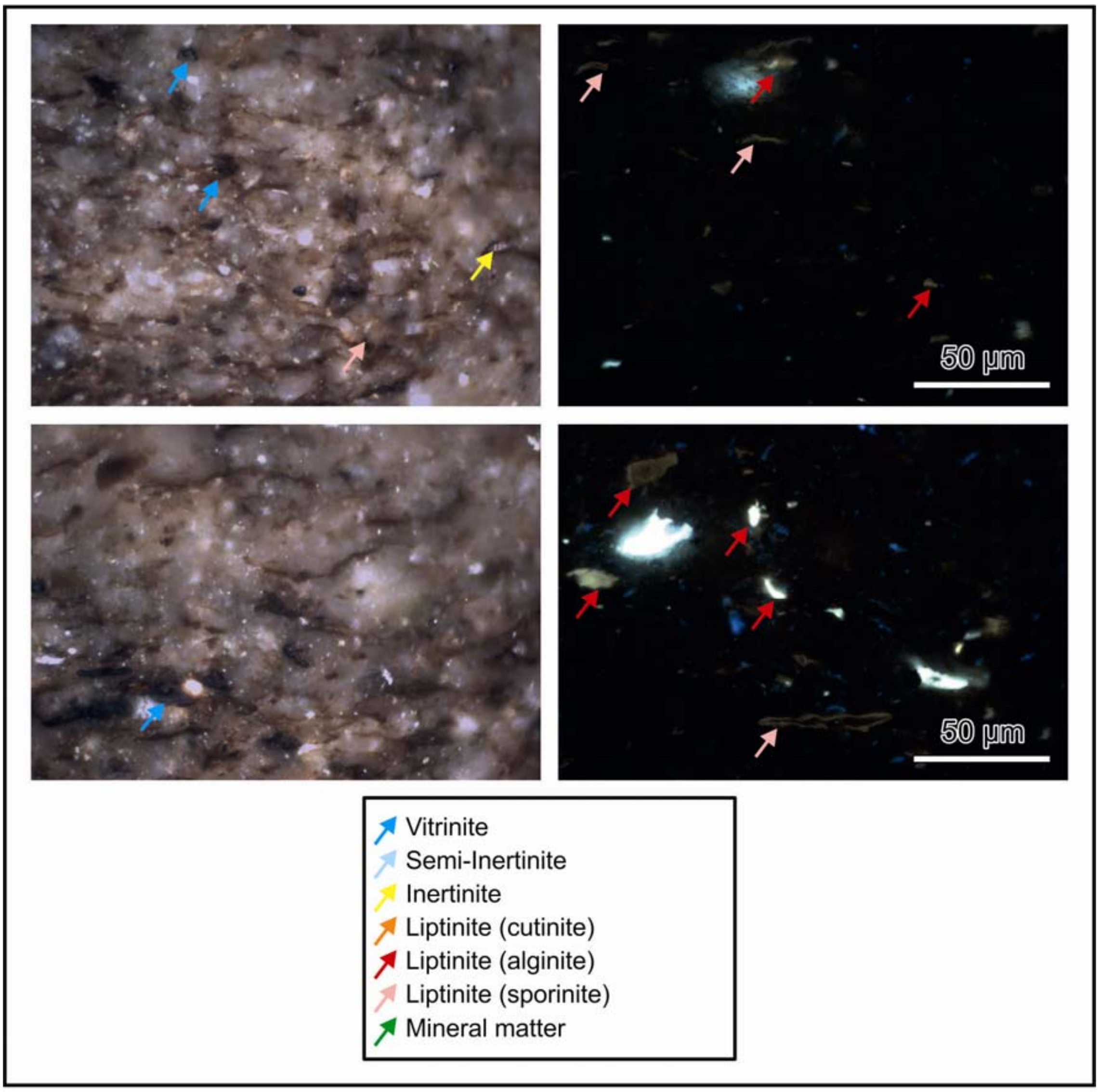
Rr [%]- random vitrinite reflectance, s-standard deviation, n-number of measurements



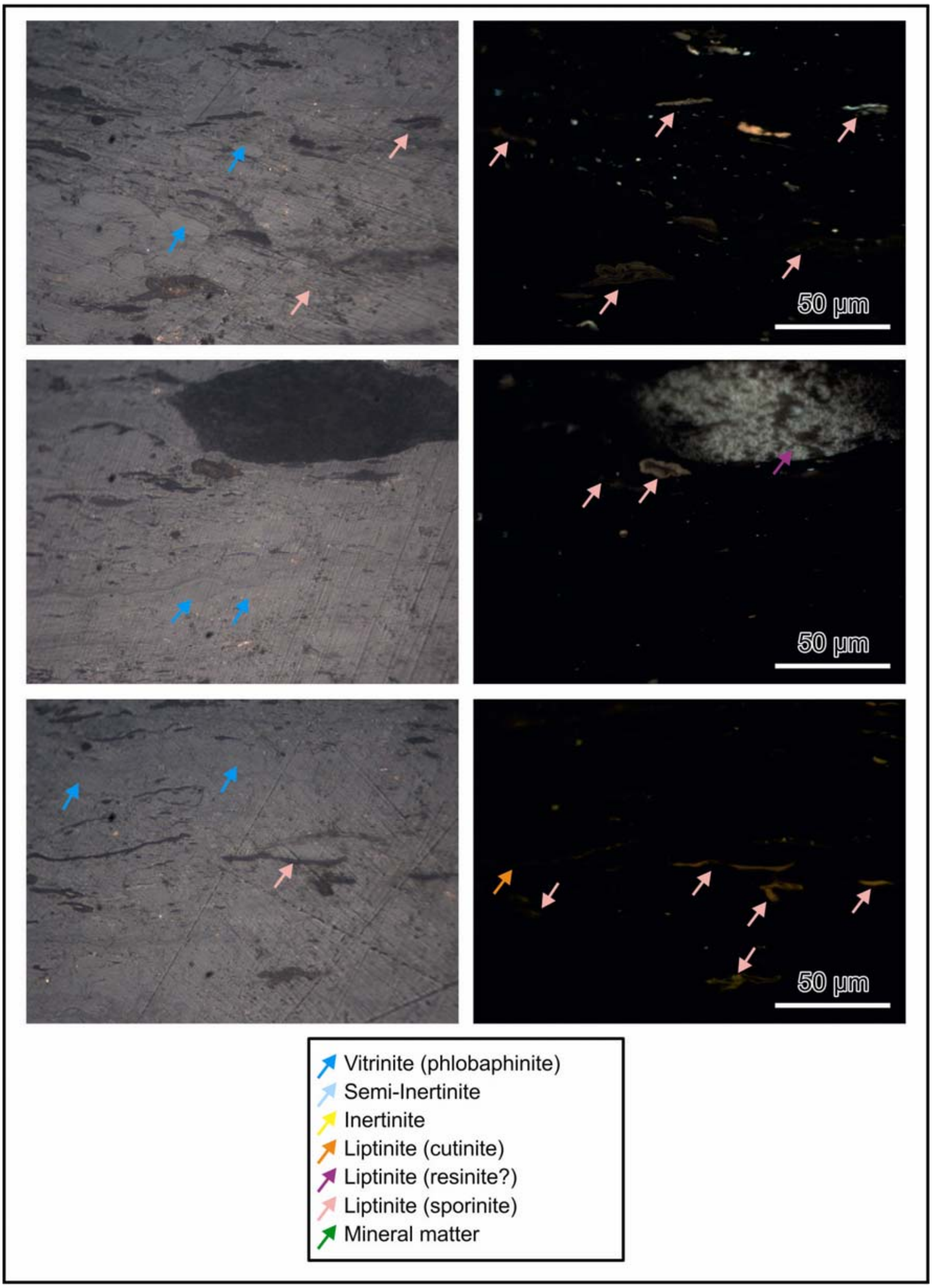
Microphotographs (oil immersion) of sample G016496. Photographs are taken using incident white light and fluorescing light (lower right side).



Microphotographs (oil immersion) of sample G016500. Photographs are taken using incident white light.



Microphotographs (oil immersion) of sample G016504. Photographs are taken using incident white light (left side) and fluorescing light (right side).



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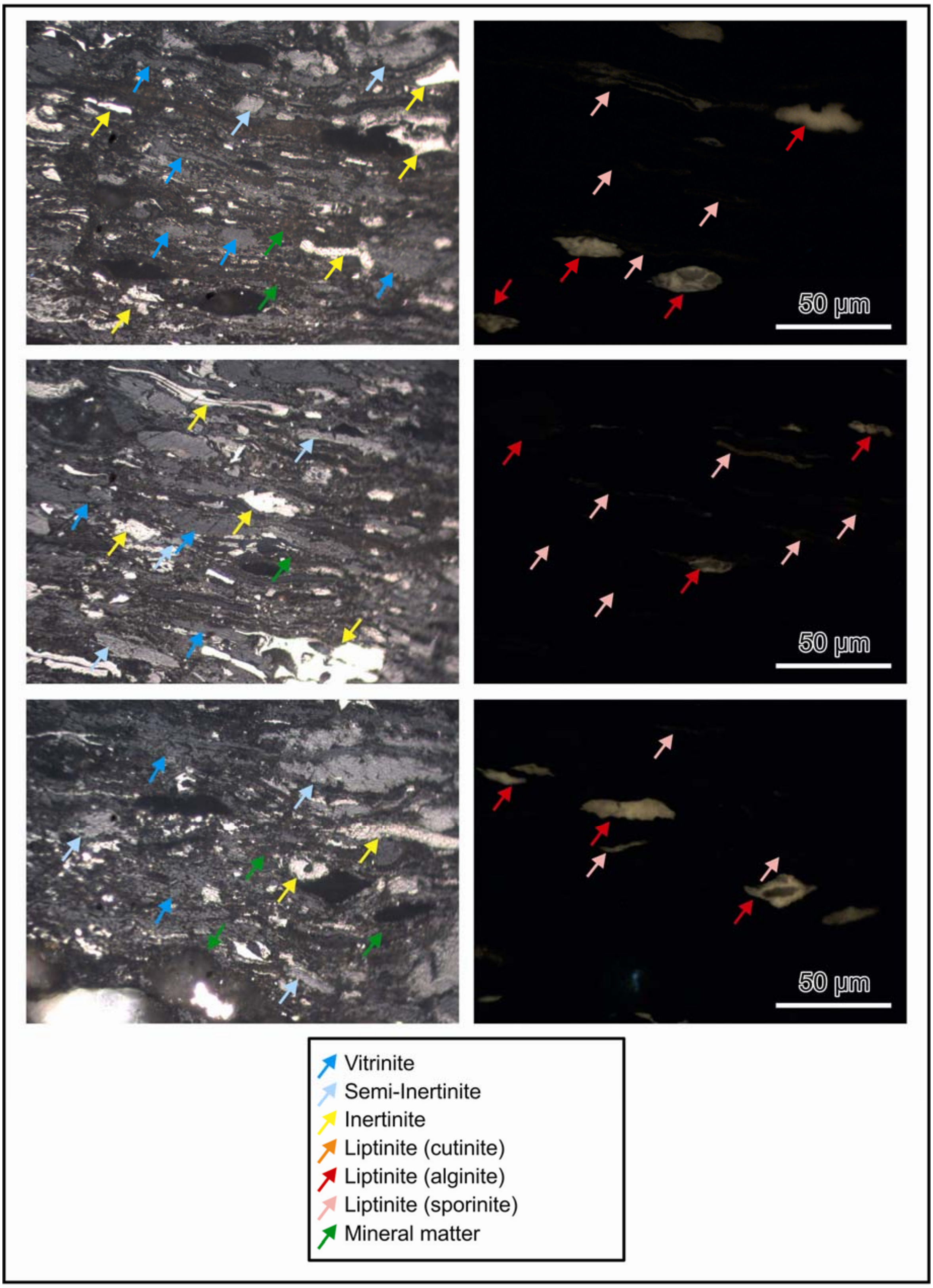
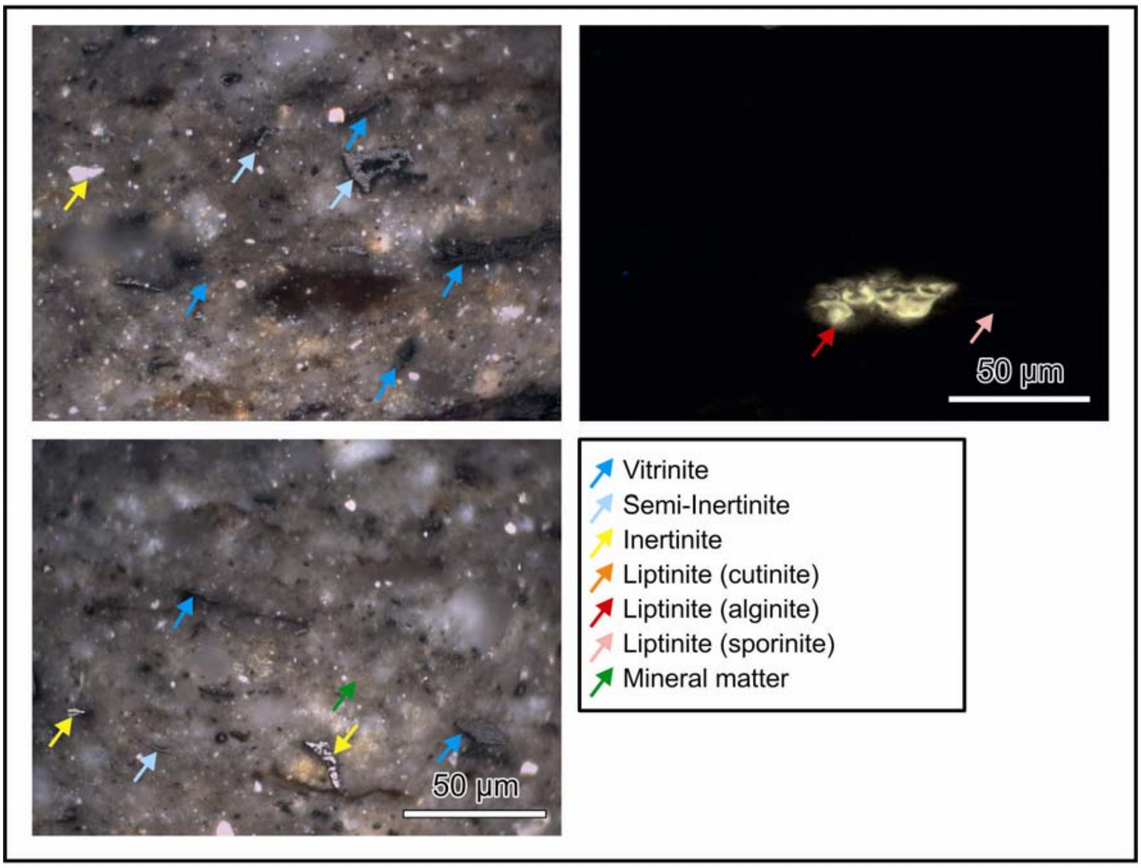
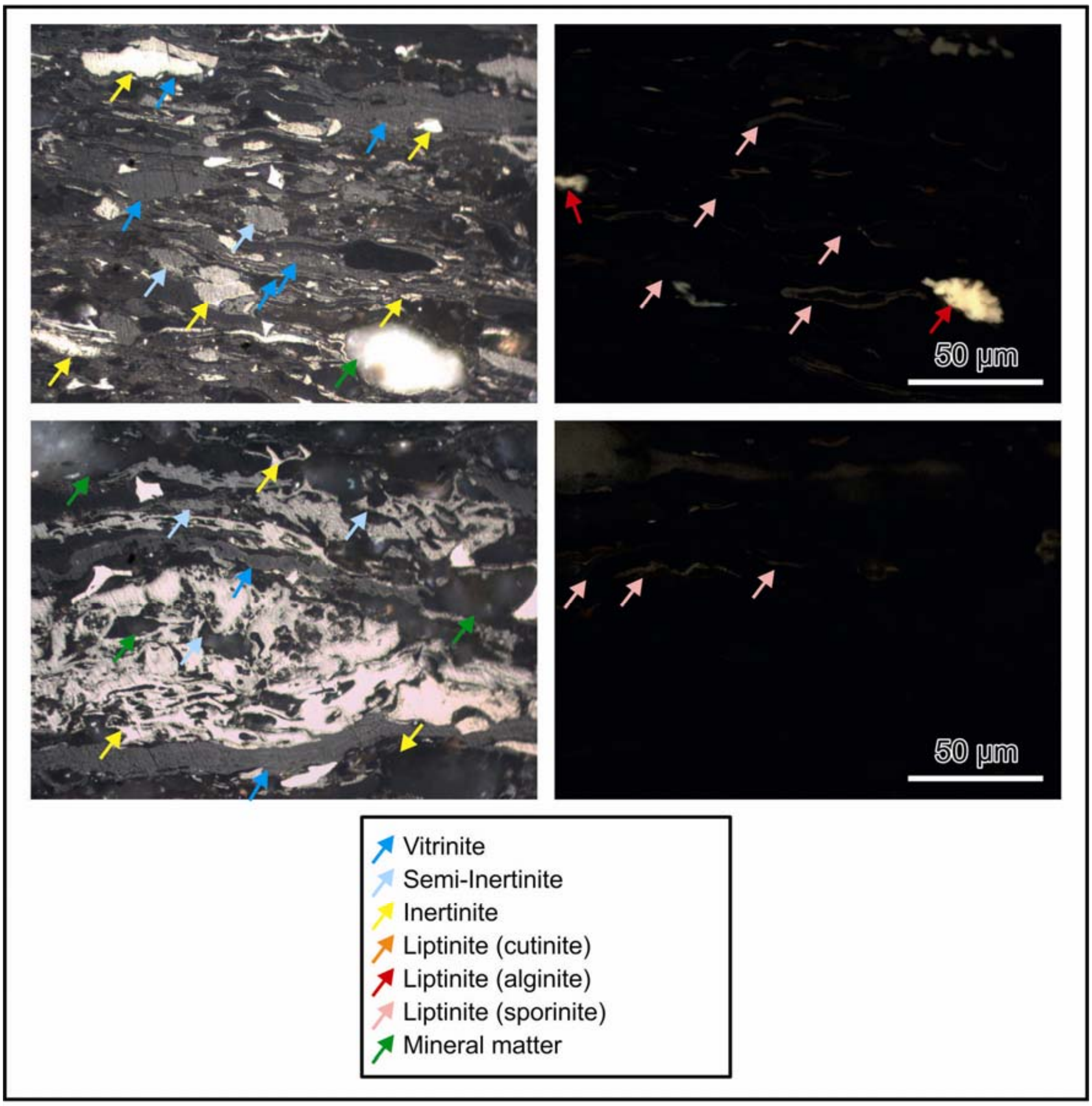


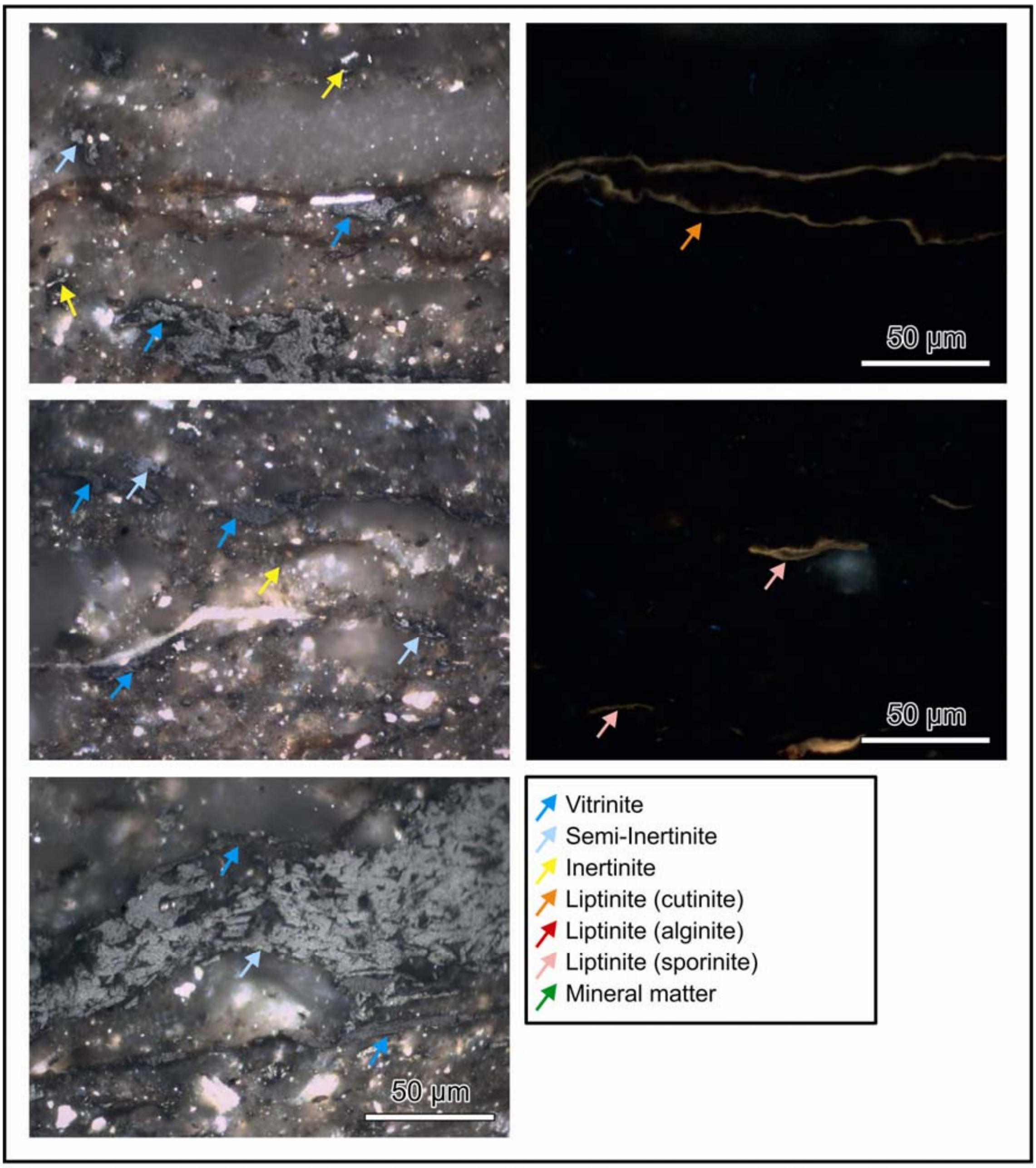
Microphotographs (oil immersion) of sample G016511. Photographs are taken using incident white light (left side) and fluorescing light (right side).



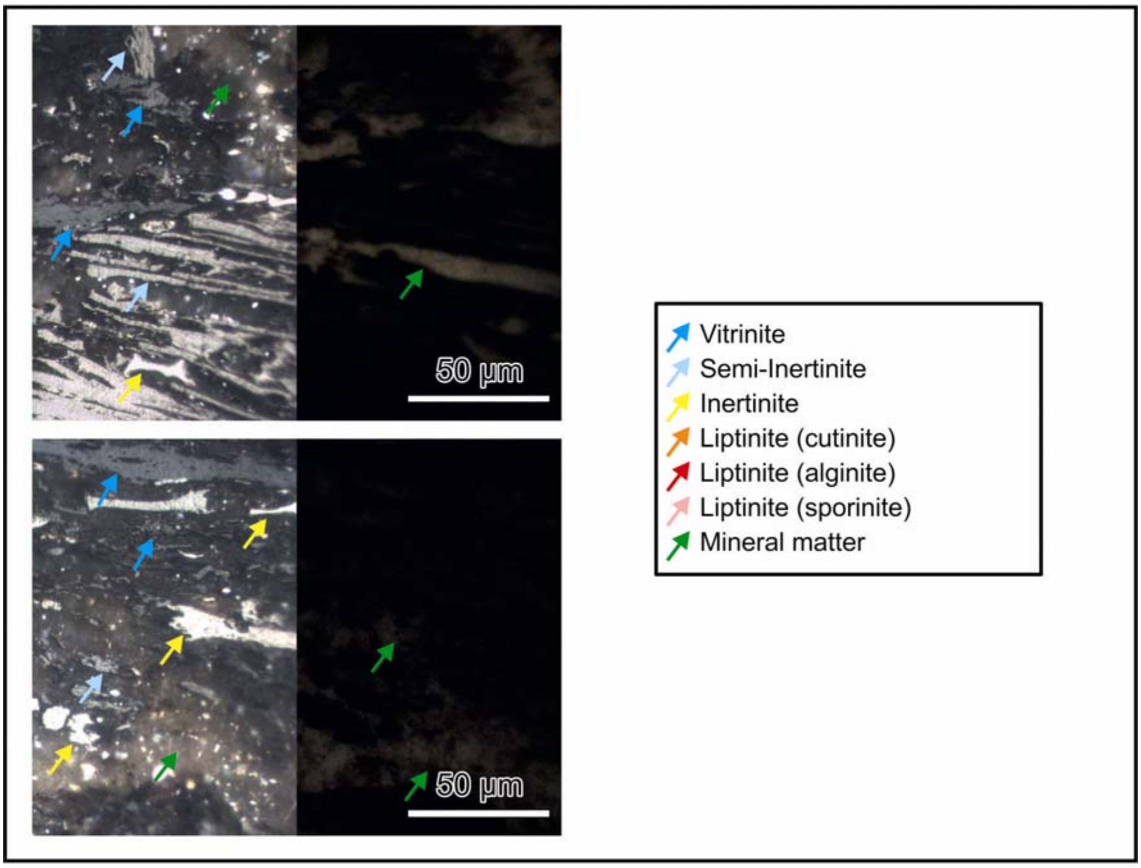
Microphotographs (oil immersion) of sample G016513. Photographs are taken using incident white light (left side) and fluorescing light (right side).



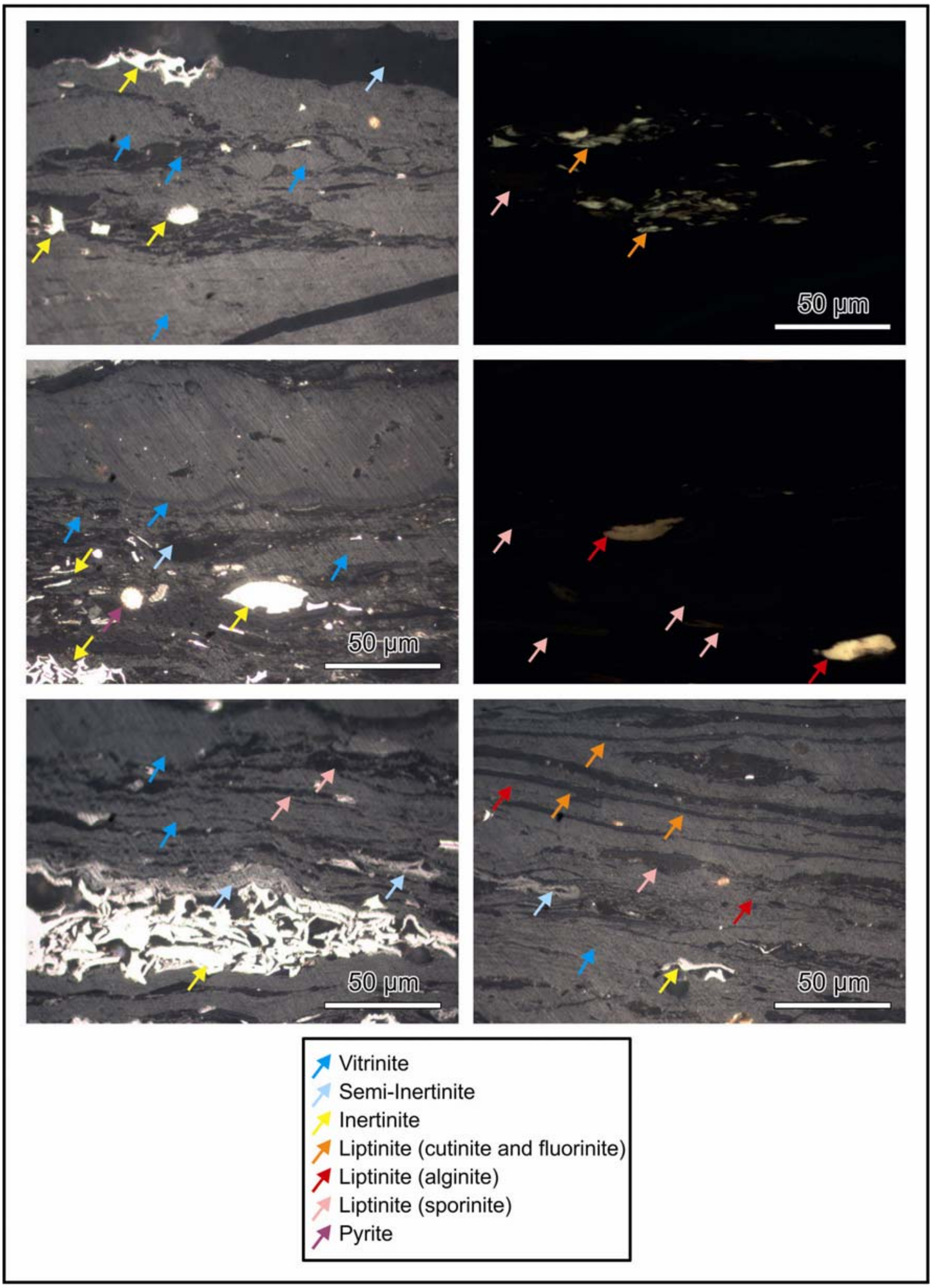
Microphotographs (oil immersion) of sample G016522. Photographs are taken using incident white light (left side) and fluorescing light (right side).



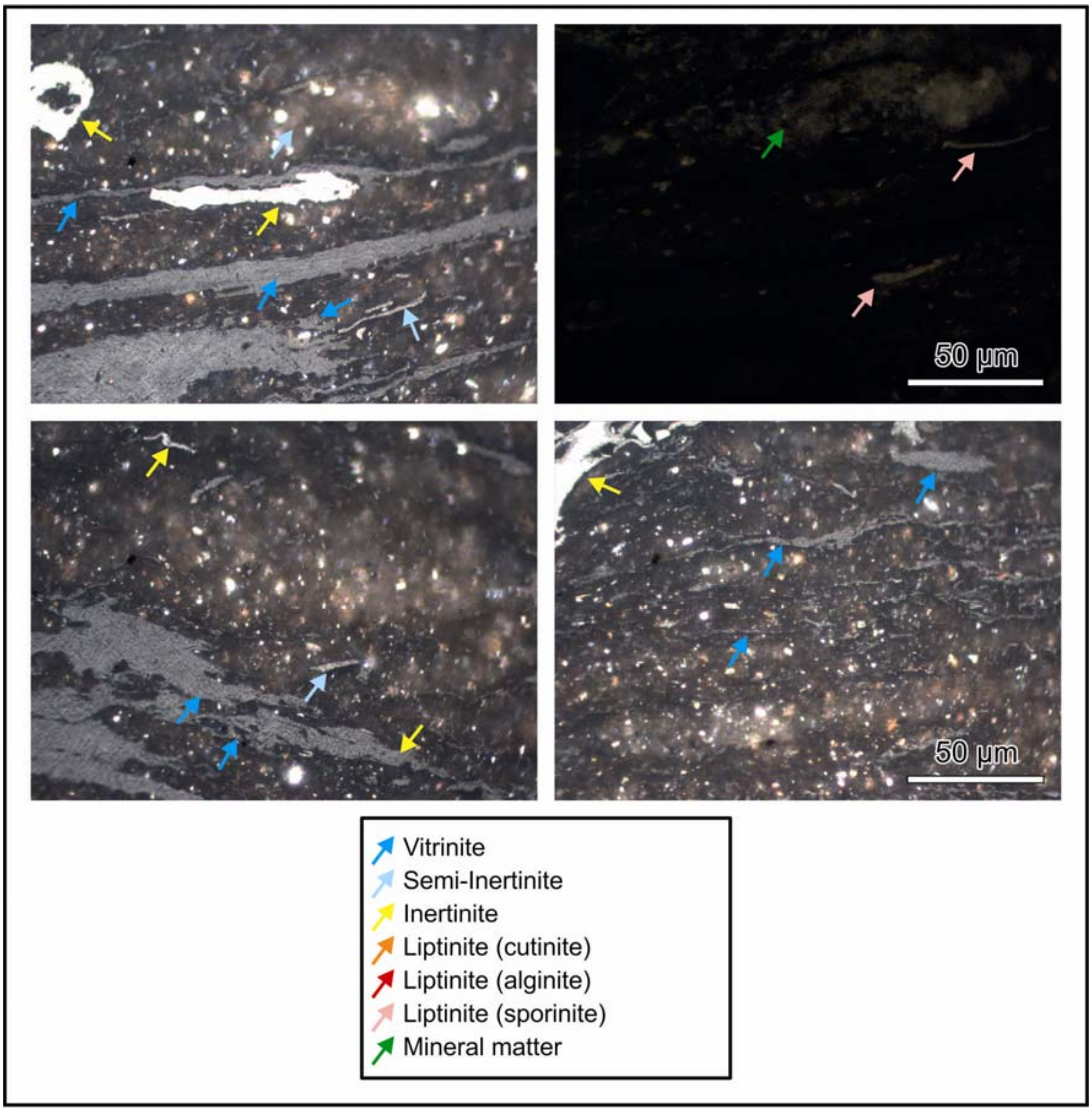
Microphotographs (oil immersion) of sample G016524. Photographs are taken using incident white light (left side) and fluorescing light (right side).



Microphotographs (oil immersion) of sample G016531. Photographs are taken using incident white light (left side) and fluorescing light (right side).



Microphotographs (oil immersion) of sample G016535. Photographs are taken using incident white light (left side) and fluorescing light (right side).



Microphotographs (oil immersion) of sample G016539. Photographs are taken using incident white light (left side) and fluorescing light (right side).