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Geology of the southern margin of the Taoudeni basin (Bamako area)

Introduction

The objective of this report is to summarize the geological knowledge about stratigraphy, lithology, sedimentology, and petrology of the Neoproterozoic rocks of Block #25.

This report is based on data from three sources:

1. F1 and F2 core and lab work performed on the samples from it,
2. Field work in the Bamako area, and
3. Publications and geological maps of the area (e.g. Carte Photogeologique du Mali Occidental au 1/200 000).

Based on this data, a composite stratigraphic column and regional cross-section between the Wells F1 and F2 and Well B in Bourakebougou have been produced. This cross-section integrates subsurface stratigraphic classification based on the core with the surface formations shown on geological maps.

The surface to subsurface correlation, lithologic, petrographic, and sedimentologic description of the Neoproterozoic succession that are presented in this report should serve as a frameworrk for exploratory drilling in the area.

Geological setting

Block #25 is located near the southern boundary of the Taoudeni Basin (Fig. 1).

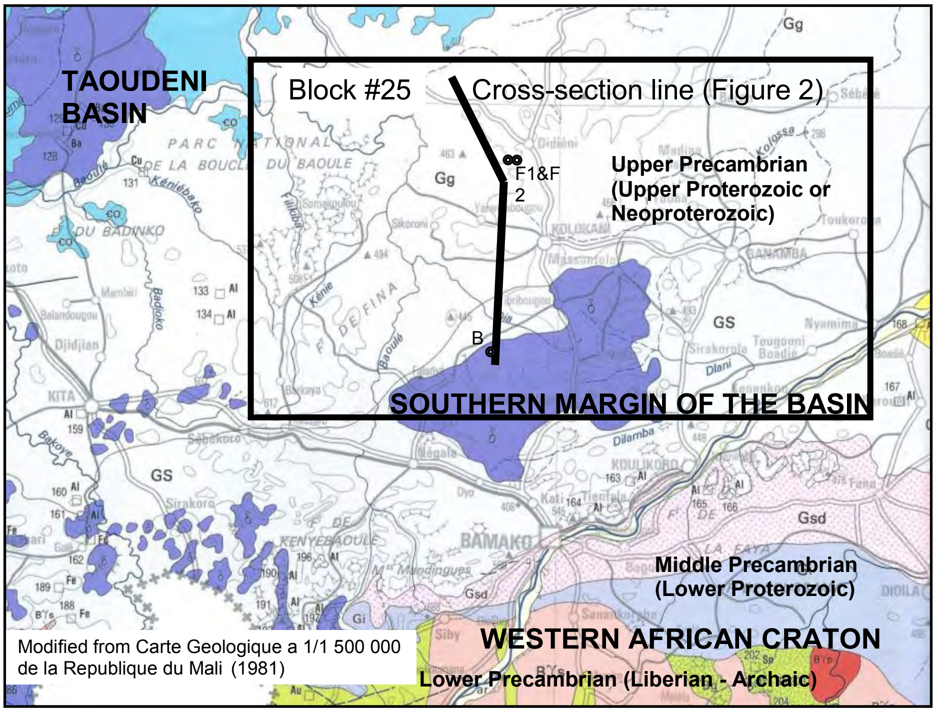
Bedrock within the in the south-central part of the area consists of Neoproterozoic sedimentary rock and intrusive rock.

Description of geology of the area is based on the core from wells F1 and F2 and some reconnaissance field trips along the cross-section line marked on Figure 1.

The cross section on Figure 2 is the first attempt for integrating the surface geology (Carte Photogeologique du Mali Occidental au 1/200 000, Feuille ND-29-X, Kolokani, 1986) with subsurface information from the wells F1, F2 and B.

Fig. 1

Geological setting of the Block #25



Stratigraphy and lithology

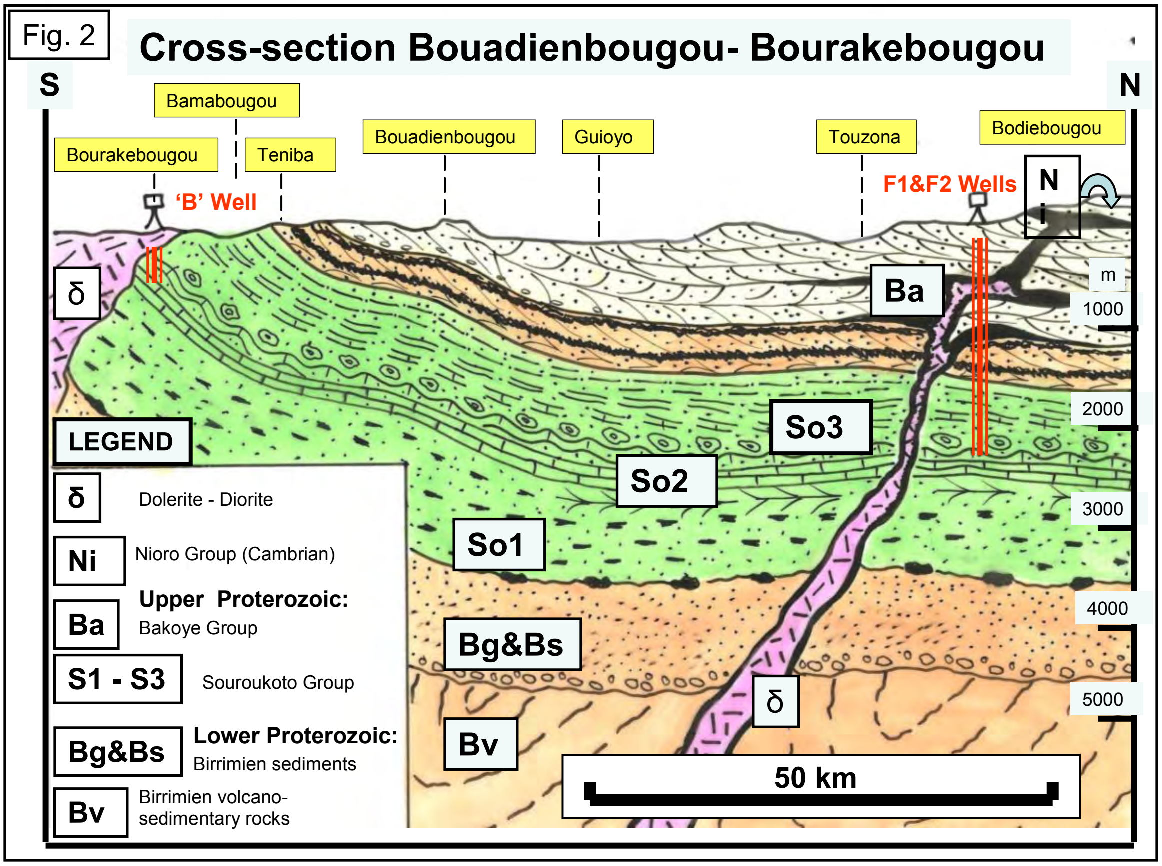
The basement belongs to the Leo Shield of the Western African Craton (Figure 1) and influences the seismic and gravimetric images of the area.

Its lower part called Liberian is of Lower Precambrian (Archean) age and it is highly metamorphosed, migmatized and granitized about 2700 Ma ago.

The Archean is represented by granites, migmatites, anorthosites, charnockites and schists with hyperaluminous and ferruginous horizons (magnetite quartzites).

The upper part of the basement is called Birrimian and it is of Middle Precambrian age (metamorphosed and granitized about 1800 Ma ago). It contains volcanic spillitic-keratophyric rock association (Bv on Figure 2), and flysch-like rock association marked Bg&Bs on Figure 2 (graywackes, conglomerates, quartzites, arkoses and schists).

The whole Birrimien succession is intruded by granitic bodies which might be in hypovolcanic facies.



The Taoudeni basinal rocks of the area belong to the Neoproterozoic.

The Neoproterozoic sediments are subdivided into three groups of formations:

- the Sotuba (St),
- the Souroukoto (So) and
- the Bakoye Groups (Ba).

The Sotuba strata form bedrock in the Bamako area south of the Niger River valley and the Souroukoto sandstone north of the valley[1].

The Sotuba strata (St) consists of quartzites and sandstone with glauconite and the basal Souroukoto sandstones are more resistant and form steep escarpments northwest of the Niger River between Sibi and Tabou (Figure 3) and in Bamako (Figure 4).

[1] (cf. Carte Photogeologique du Mali Occidental au 1/200 000, Feuille ND-29-IV, Bamako-Ouest, 1988 and Carte Photogeologique du Mali Occidental au 1/200 000, Feuille ND-29-V, Bamako-Est, 1988).

Two diagnostic sedimentary structures are the most conspicuous in the basal Souroukoto sandstone.

Firstly, the bimodal distribution of the clastic particles is very common (Fig. 3). Pebble fraction is suspended within the medium grained matrix which produces diamictic structures.

Secondly, the herringbone cross-stratification diagnostic of the intertidal environment of deposition is also common (Figure 4).

In order to explain the diamictic structure, the process of rafting by ice cover in a glacial-marginal environment is here postulated. Early season meltwater, impounded along the lateral margin of retreating cold-based glaciers, would buoyantly lift the ice cover and any frozen sediments. Higher sea levels and increased areal extent of seasonal freezing between the ice cover and the basin bed would allow for the redeposition of littoral sediments to the benthic regions.

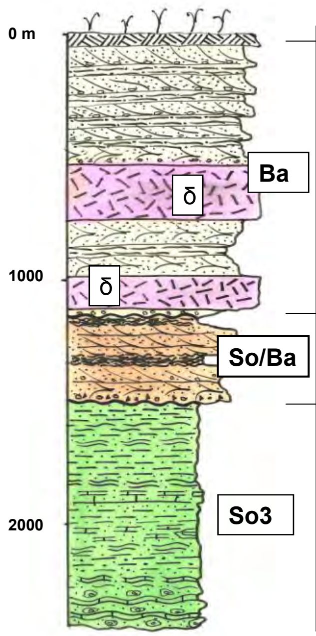
The herringbone cross-stratification is produced by water currents of the opposite direction. This is characteristic of the intertidal environment where tide and ebb currents act interchangeably. The occurrence of the diamictites and the herringbone cross-stratification strongly suggest a glacial-marginal marine environment of deposition for the basal Souroukoto sandstone.

Neither the basal (So1) nor the middle (So2) Souroukoto strata have been penetrated by F1 and F2 wells (Figure 2). Detail examination of the core and the reconnaissance in the area between Bodiebougou and Bourakebougou suggests that the boreholes have been drilled to just above the boundary between the third and the second member of the Souroukoto Group (Figure 5).

The stratigraphic succession penetrated by the F1 and F2 wells has been subdivided into three intervals. The lower interval belongs to the Souroukoto Group (So3) and the upper interval to the Bakoye Group (Ba). These two intervals are separated by an interval of transition strata designated by So/Ba symbol on Figure 5.

Fig. 5

Composite stratigraphic column of the F1&F2 Wells



Laterite

Medium-grained sandstone interstratified with fine sandstone and mudstone. Coarse sand fraction of diamictite character present (Fig. 13B). Cross-bedding common. Intertidal to supratidal depositional environment.

Two prominent layers of diorite. One in the lower and one in the upper part of the interval.

Unconformity bounded interval of black shale and medium-grained, cross-stratified sandstone. Intertidal environment of deposition.

Fine-grained sandstone, siltstone and pelitic limestone. Algal lamination and algal balls structures present (Fig. 6-9). Double mud drapes and other tidal lamination (Figs. 10-11) common. Medium grained sandstone rare. Sedimentary structures suggest deposition in subtidal depositional environment. Predominance of very fine and fine clastics suggest transport from coastal dunes.

Sedimentology and depositional environment

Diagnostic sedimentary structures identified in the core of wells F1 and F2 clearly indicate a shallow marine, subtidal to supratidal depositional environment.

Predominance of fine grained quartz sand and silt (dust) fraction strongly suggests transport from coastal dunes. The supply of clastic material from the coastal areas was not steady which allowed for an intermittent development of algal structures.

The maximum development of algae took place in the stratigraphic interval So/Ba between the Souroukoto and Bohai strata (Fig. 5).

This interval is interpreted to be an intertidal lagoon environment. The black shale which is the product of this environment requires further research because it raises questions.

Is the black shale from the So/Ba interval (Fig. 17) the source of hydrocarbons?
Is there yet another organic rich interval within the lower part of the Souroukoto Group which is deeper or farther out, that has not been penetrated by the F1 and F2 wells?

Further drilling, sedimentological research and basin analysis is required in order to address these questions.

Petrography

Thin sections of the main rock types have been studied under a polarizing microscope. The following samples have been analyzed:

Carbonate rocks:
1. F1 – 1080m
2. F1 – 1978m
3. F2 – 1297m
4. F2 – 2109m
5. F2 – 2196m
6. F2 – 2201m
7. F2 – 2416m

Sandstones:
8. F1 – 236m
9. F1 – 1444m
10. F2 – 1461m
11. Tabu #1

Igneous rocks:
12. F1 - 549m
13. F1 – 560m

14. F1 – 665m
15. F1 – 1047m
16. F1 – 1159m
17. F2 – 1697m
18. F2 – 2174m
19. F2 – 2243m
20. #2 A5 B.Well.

Carbonate rocks under a microscope show distinct laminations which are attributed to the activity of algae (Figures 7-9). This conclusion is supported by the presence of algal structures visible in the carbonate rocks in the macroscopic scale (Figures 6 and 18).

Clastic rocks are represented by siltstone (Figure 12) and sandstone (Figures 14-16). The siltstone and very fine grained sandstone are very common especially in the lower part of the succession penetrated by F1 and F2 wells (So3 interval). These clastics have been probably delivered to the basin by wind.

Medium to coarse grained sandstone contain some feldspars but quartz grains predominate and they should be classified as quartz arenites. They are usually well sorted (Figures 14-16) but some poorly sorted diamictites are also present especially in the upper part of the succession (Fig. 13B).

Medium and coarse grained sandstone are very porous (10-15%) and should be considered as the potential hydrocarbon reservoir.

Igneous rocks has been analysed by petrologists of the Calgary Rock and material Services Inc. According to their expertise the analysed samples[2] should be classified as diorite.

The mineralogy of these rocks is dominantly plagioclase and clinopyroxene (Figures 19, 20 and 21). There are also smaller amounts of k-feldspar, biotite, and metallic opaque minerals. X ray diffraction, XRD and Elemental Dispersive Spectroscopy, EDS would have to be performed in order to identify the metallic minerals. Figure 21 shows some details of the rock. The lower center portion of the image illustrates micrographic texture, identified by the angular inter-growths. The top-left corner shows an example of a k-feldspar crystal exhibiting a symplectitic texture.

The geological significance and understanding of igneous rocks in the area requires further work. Besides the discrepancy of opinion concerning its classification (Dolerite vs. Diorite) there are still uncertainties concerning:

- the age of its emplacement into the Neoproterozoic succession and
- its potential role as a source of heat into the petroleum system, and
- mineralization of the Neoproterozoic succession.

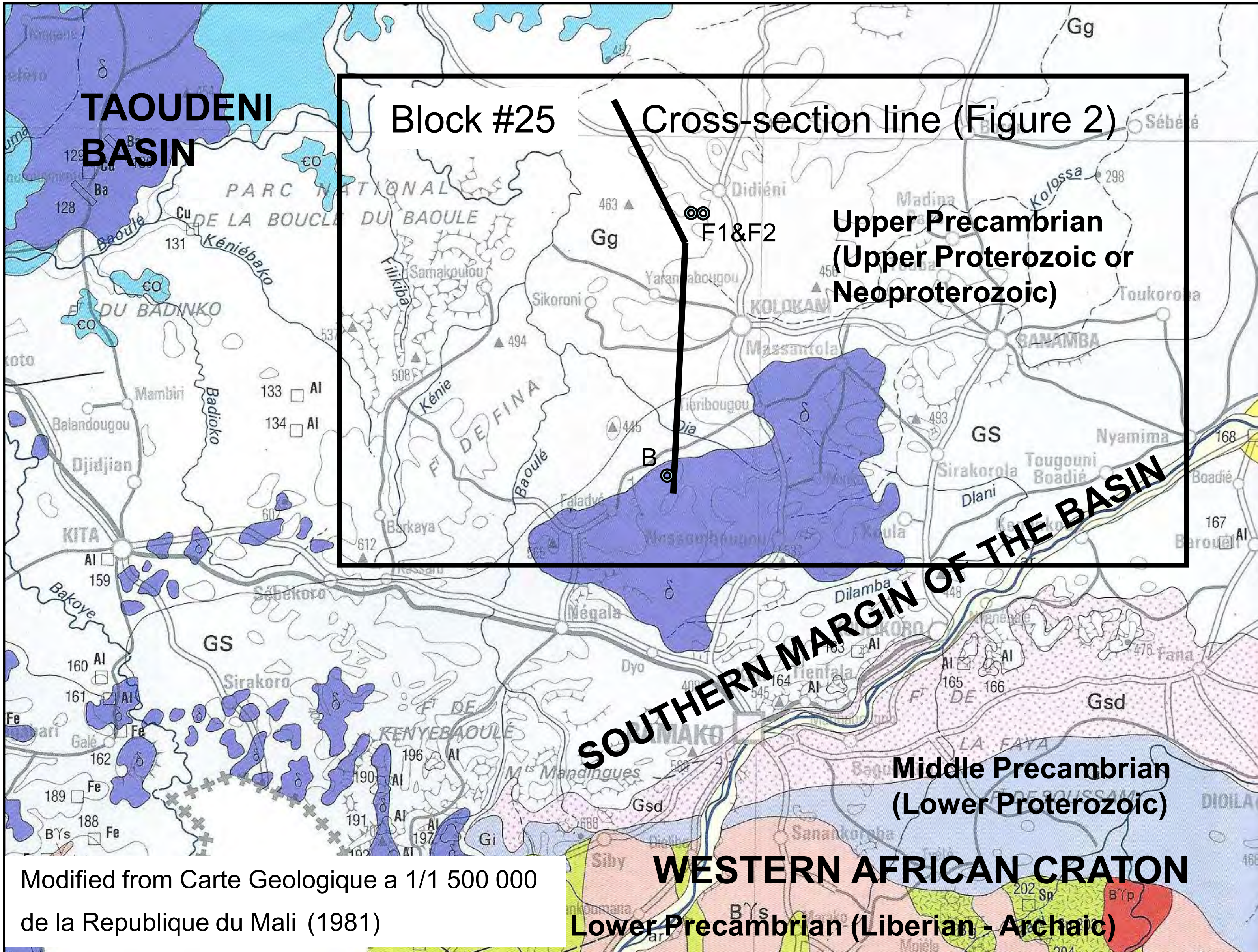
[2] (F1 – 1047m; #2 A5 B – Bourakebougou and F1 – 560m)

Judging from the observation of core from wells F1 and F2, the igneous rock in question was emplaced as a liquid which rose upwards through the basement rocks into the sedimentary rocks.

The emplacement probably occurred over a long interval of time and produced a tabular body of igneous rock which is of almost identical thickness in both F1 and F2 wells.

Fig. 1

Geological setting of the Block #25



Modified from Carte Geologique a 1/1 500 000
de la Republique du Mali (1981)

Fig. 2

Cross-section Bouadienbougou- Bourakebougou

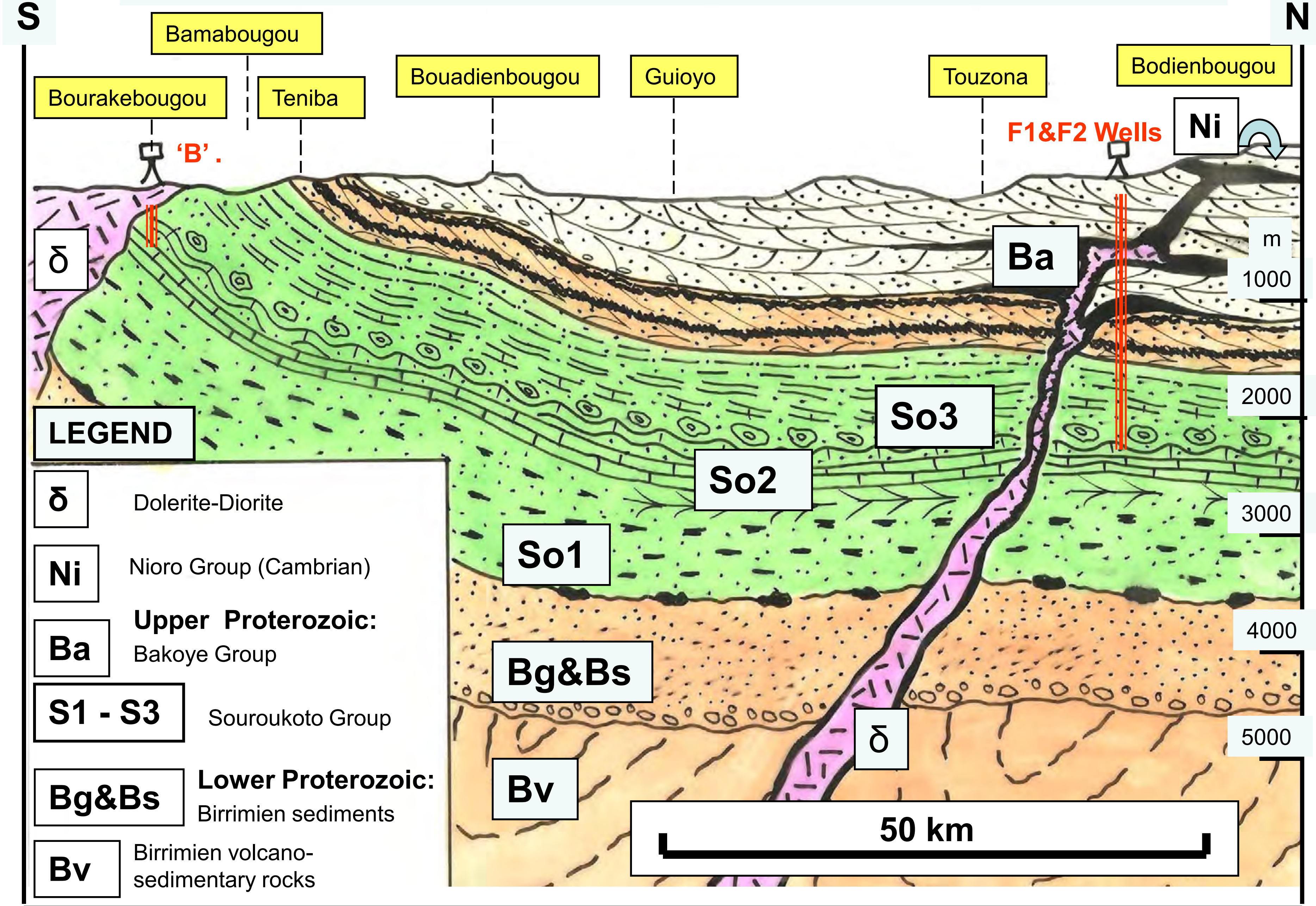


Figure 3. Basal Souroukoto sandstone (Tabou)

Figure 4. Herringbone cross-stratification. Lower Souroukoto sandstone (Bamako)

Fig. 5

Composite stratigraphic column of the F1&F2 Wells

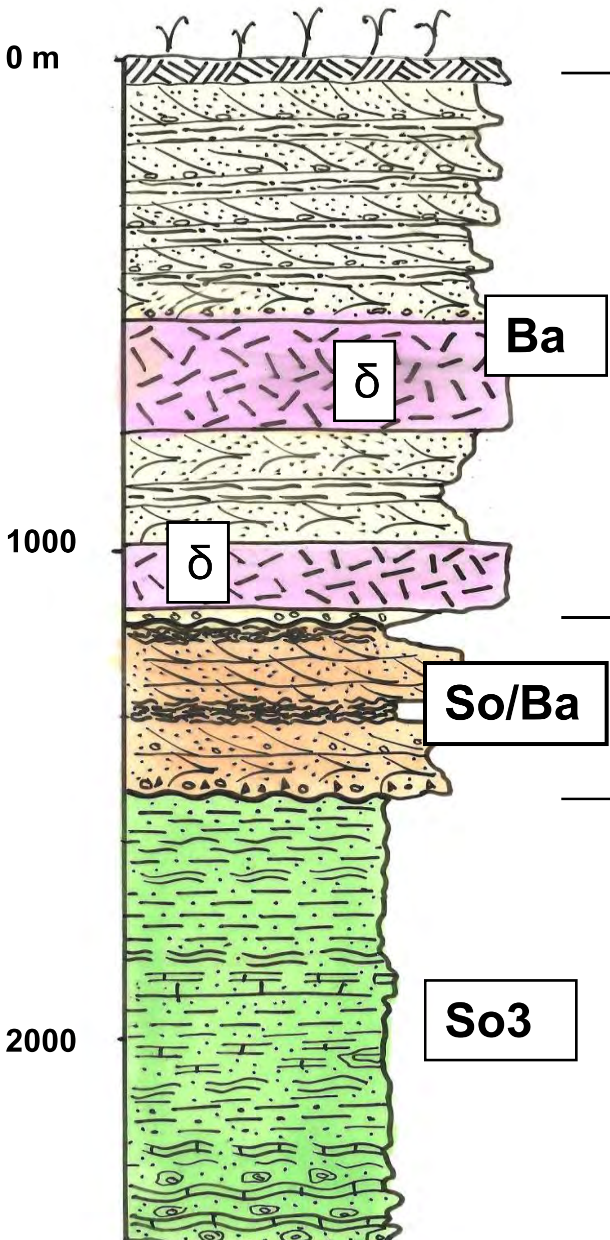


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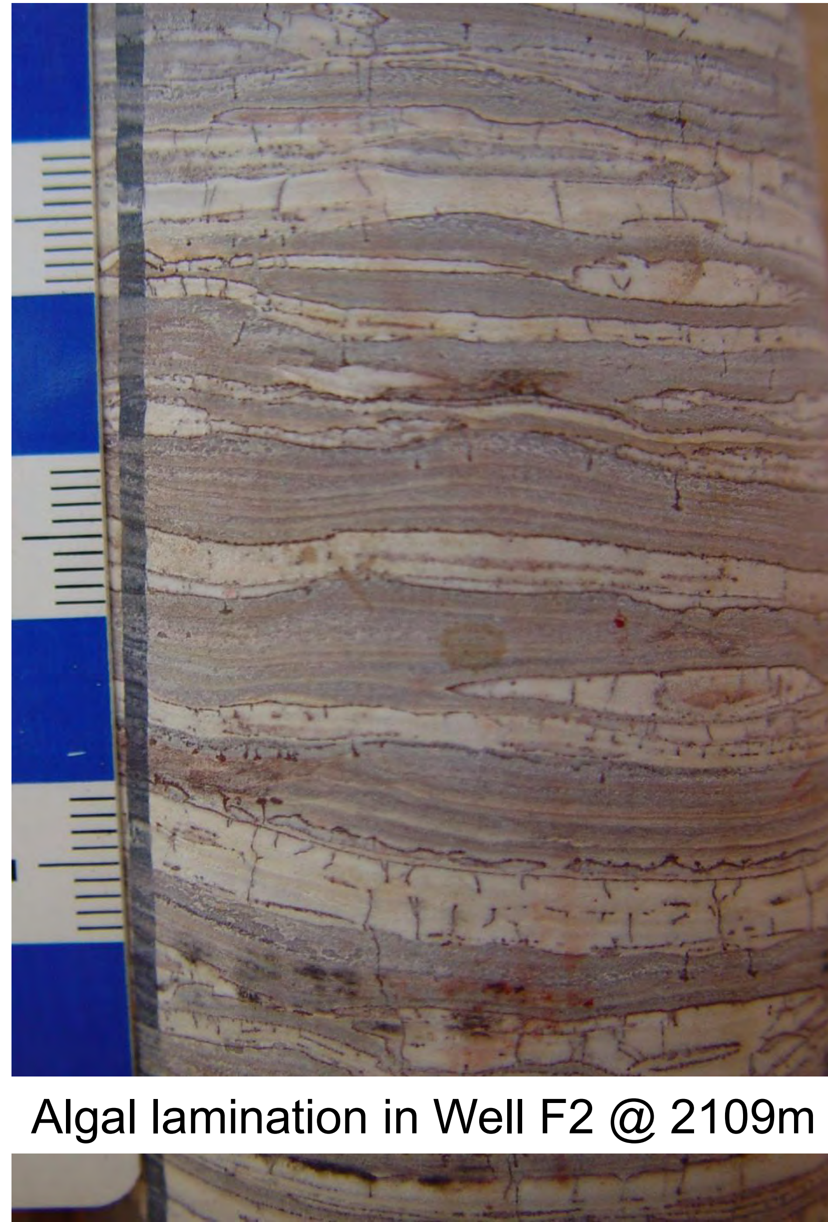
Fig. 6. Algal balls and algal lamination (So1 formation)

Algal balls in F2 @ 2201m



Algal lamination in Well F2 @ 2109m

Fig. 7. Microphotograph of algal lamination (So1 formation)

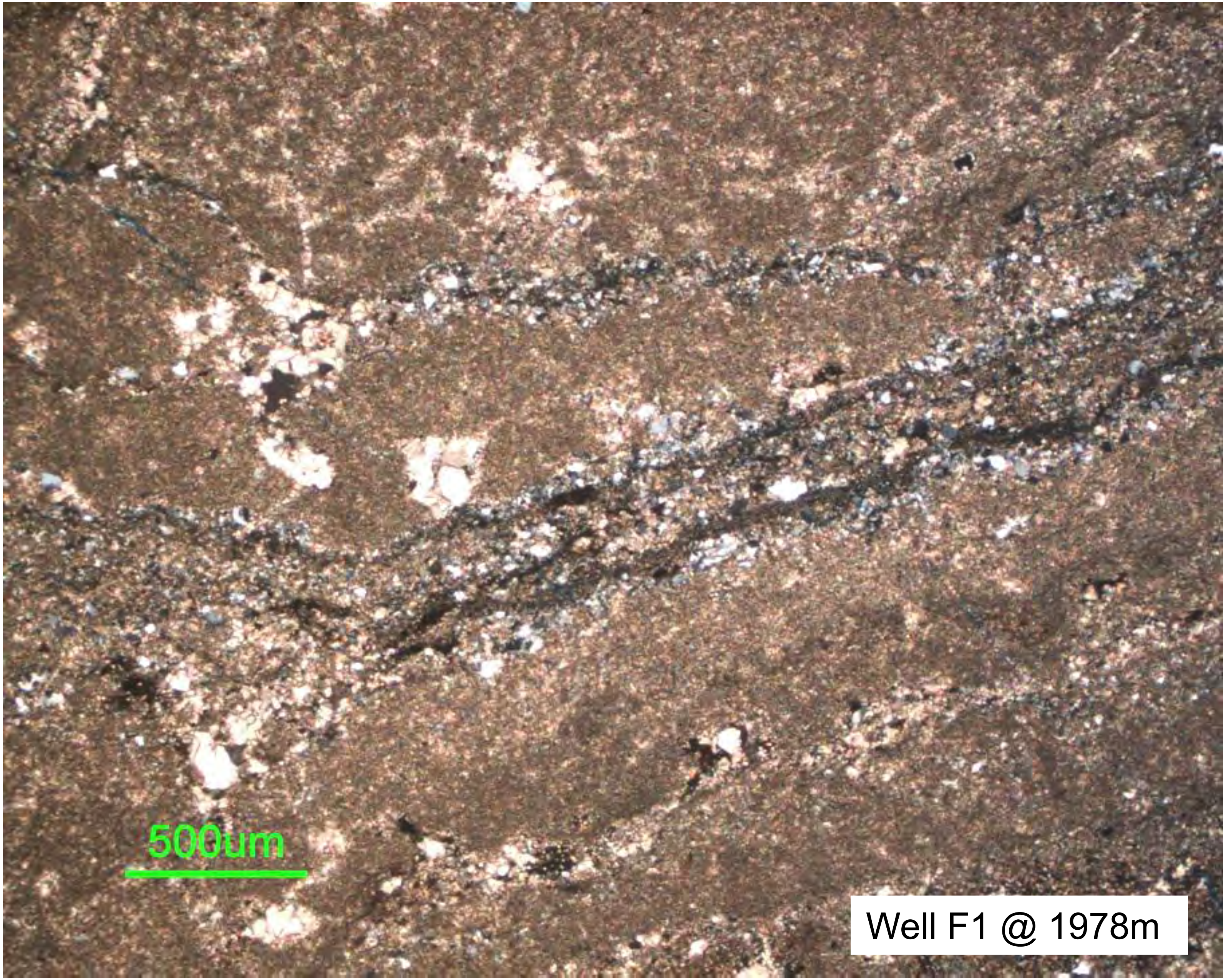


Fig.8. Microphotograph of algal lamination (So3 formation)

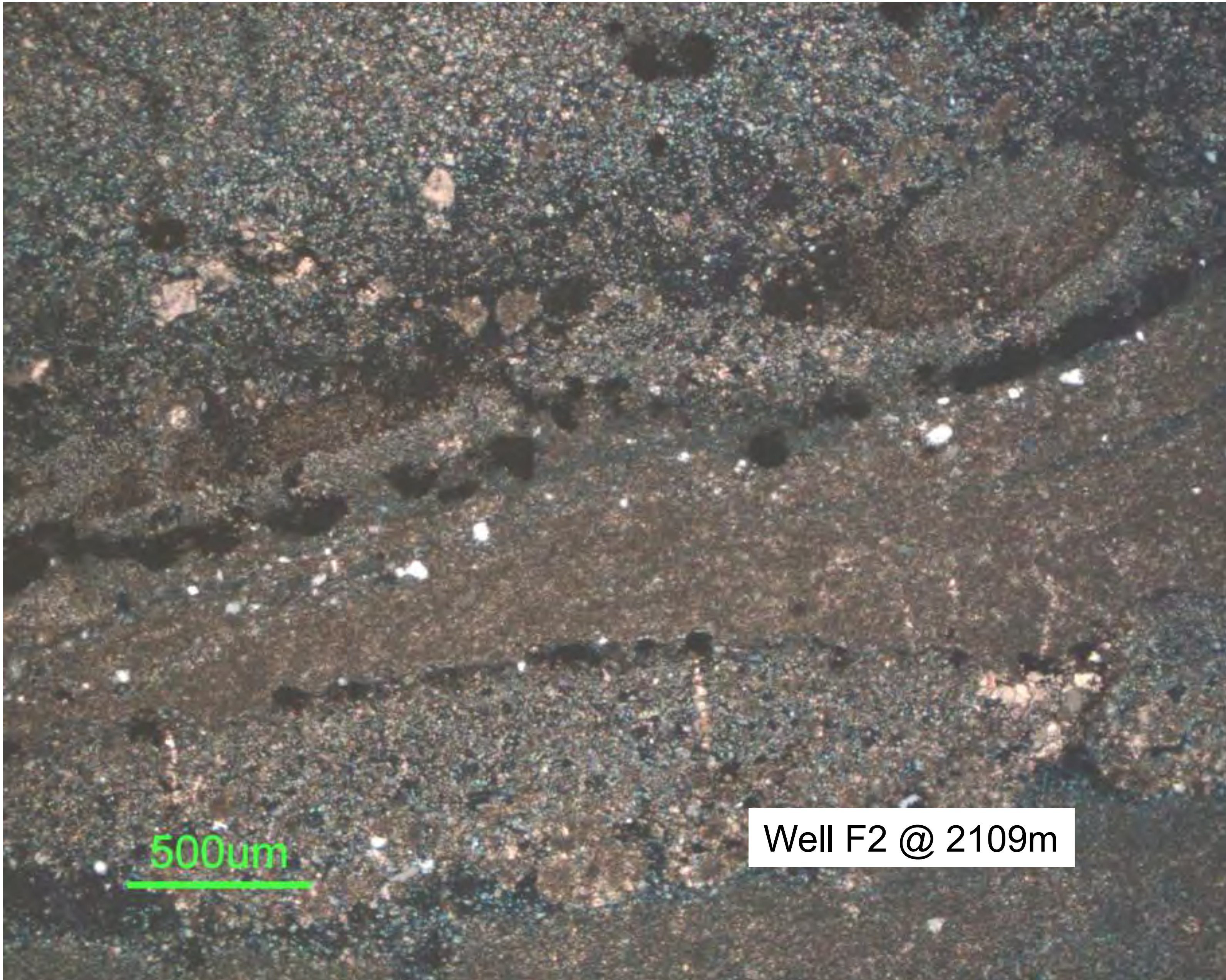


Fig. 9. Algal structure (So3 formation)

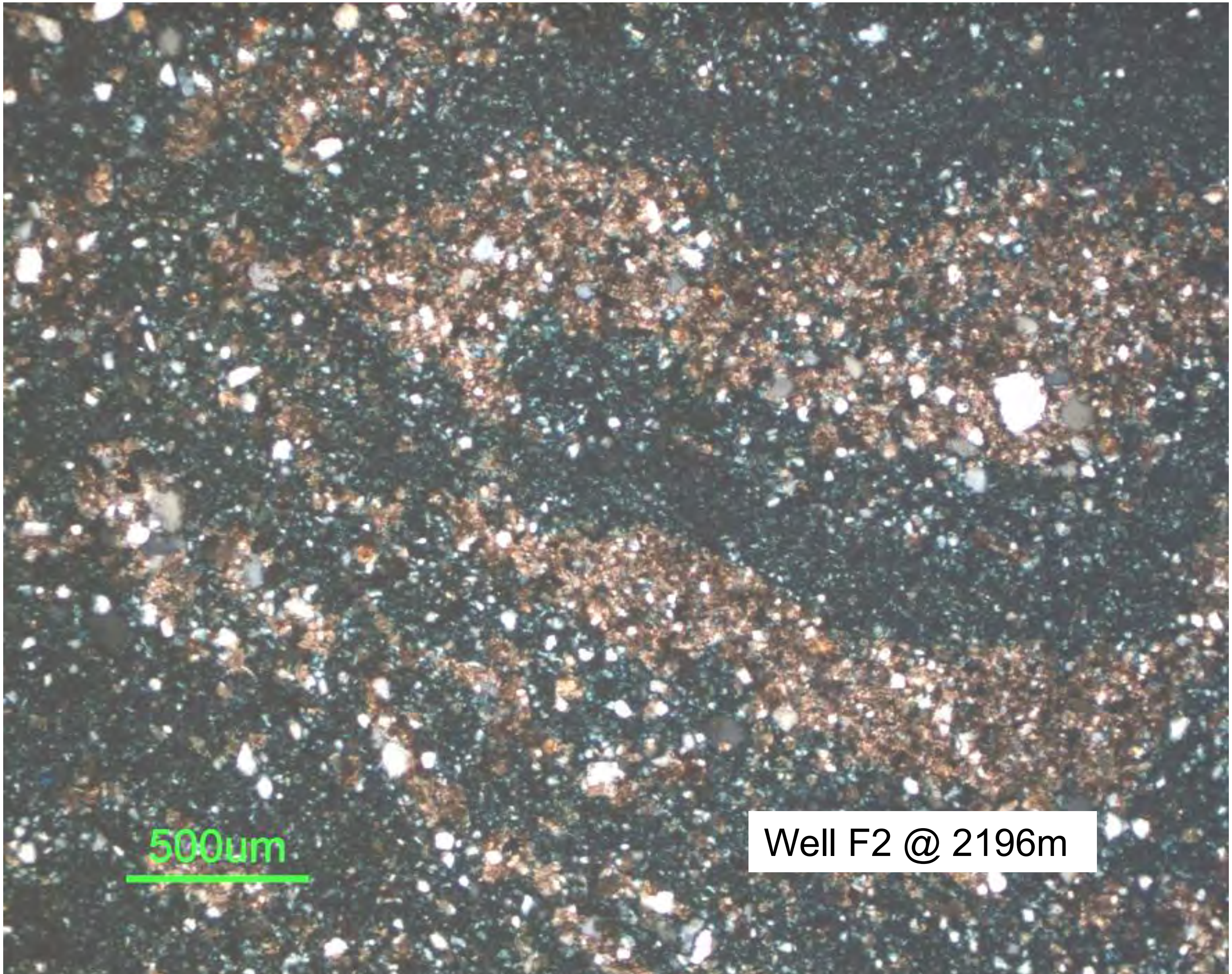
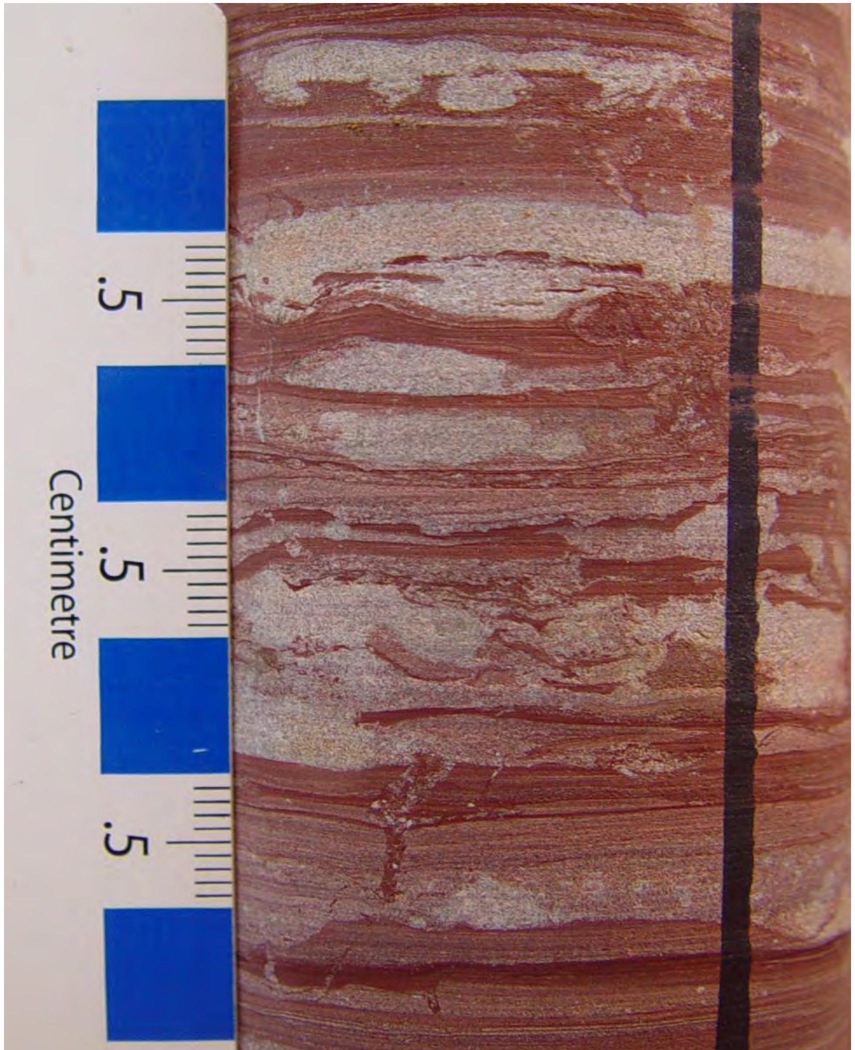


Fig. 10. Mud-draped fine-grained sandstone and siltstone (So3 formation)



Tidal lamination in Well F2 @ 1973m

Tidal lamination in Well F2 @ 1958m

Fig. 11. Partly bleached red beds with relics of tidal lamination (So3 formation)

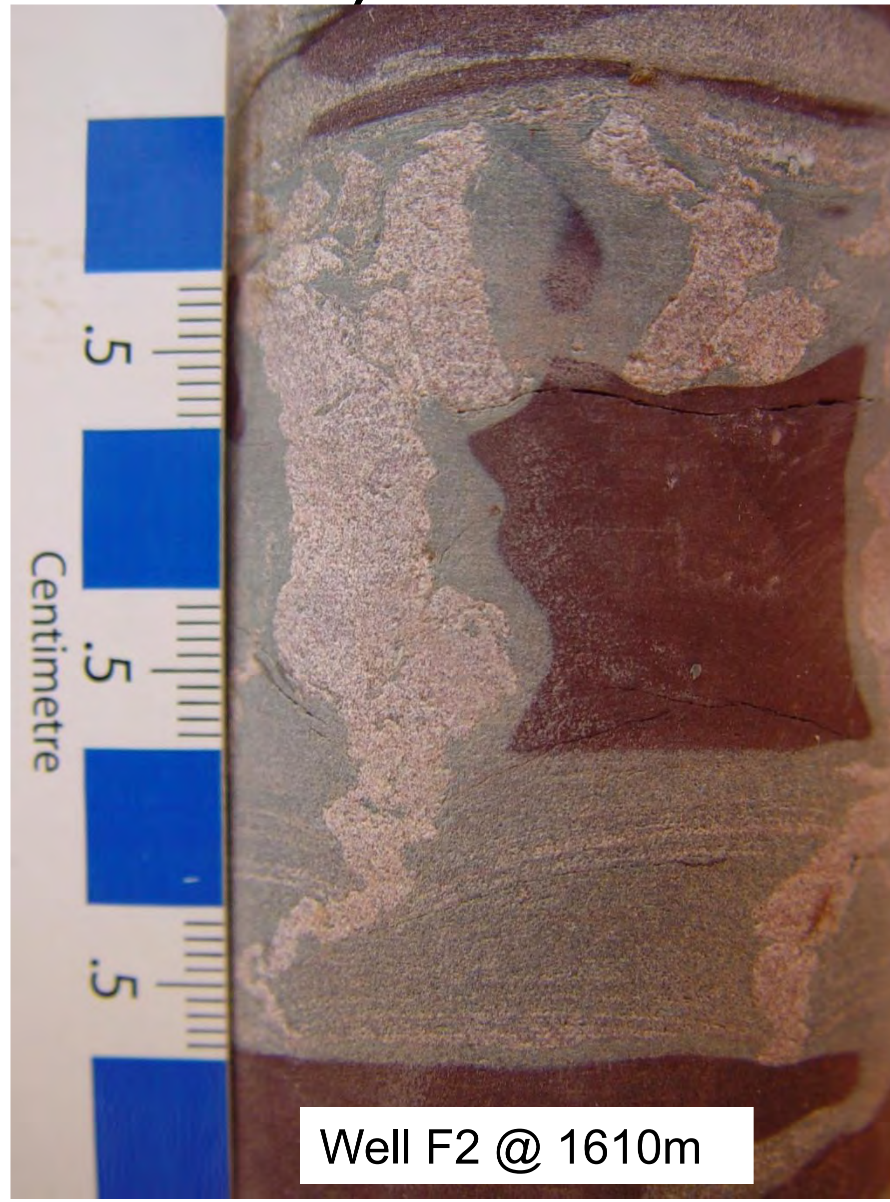


Fig. 12. Microphotograph of siltstone (So3 formation)

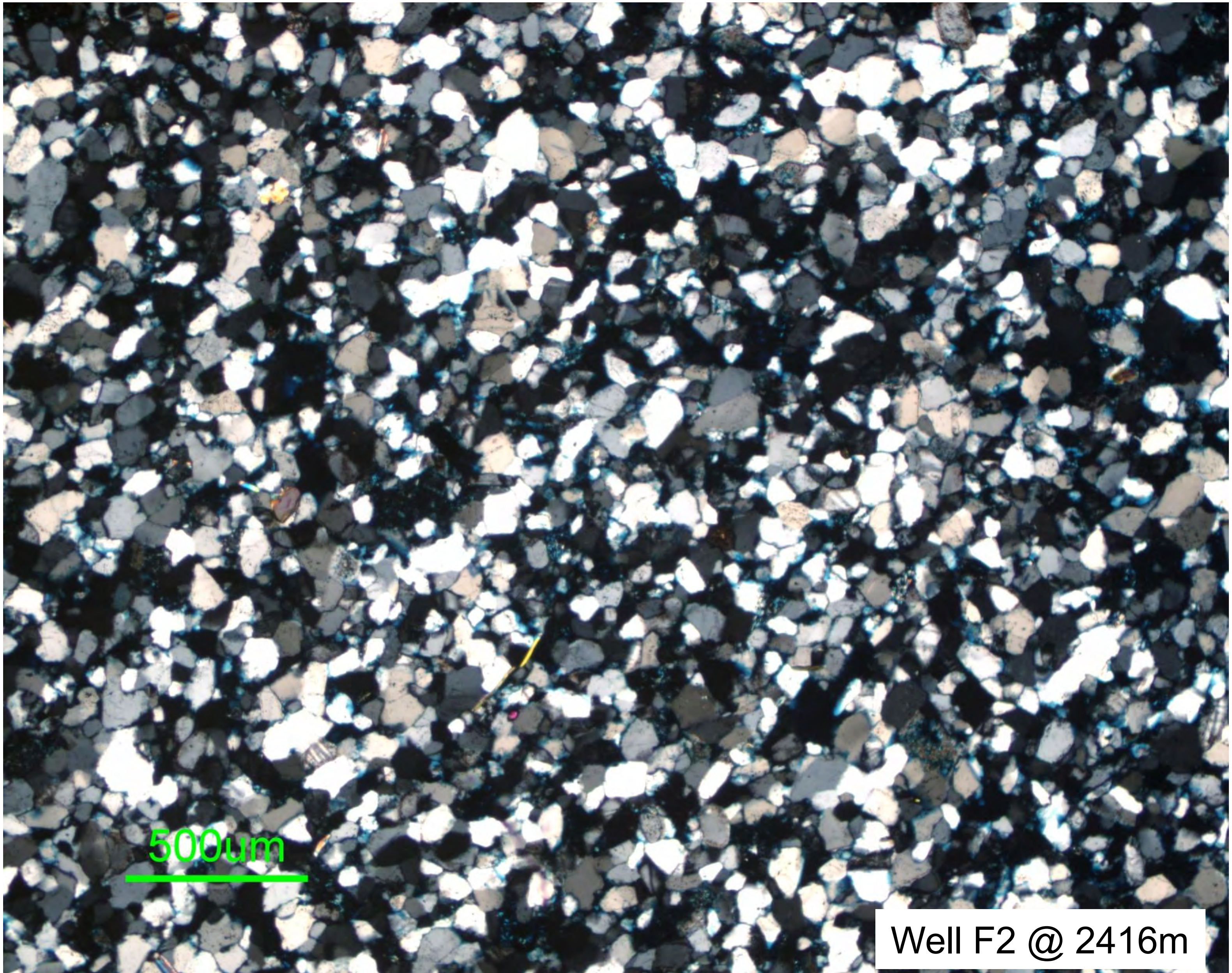


Fig. 13. Medium to coarse grained sandstone (Well F2)

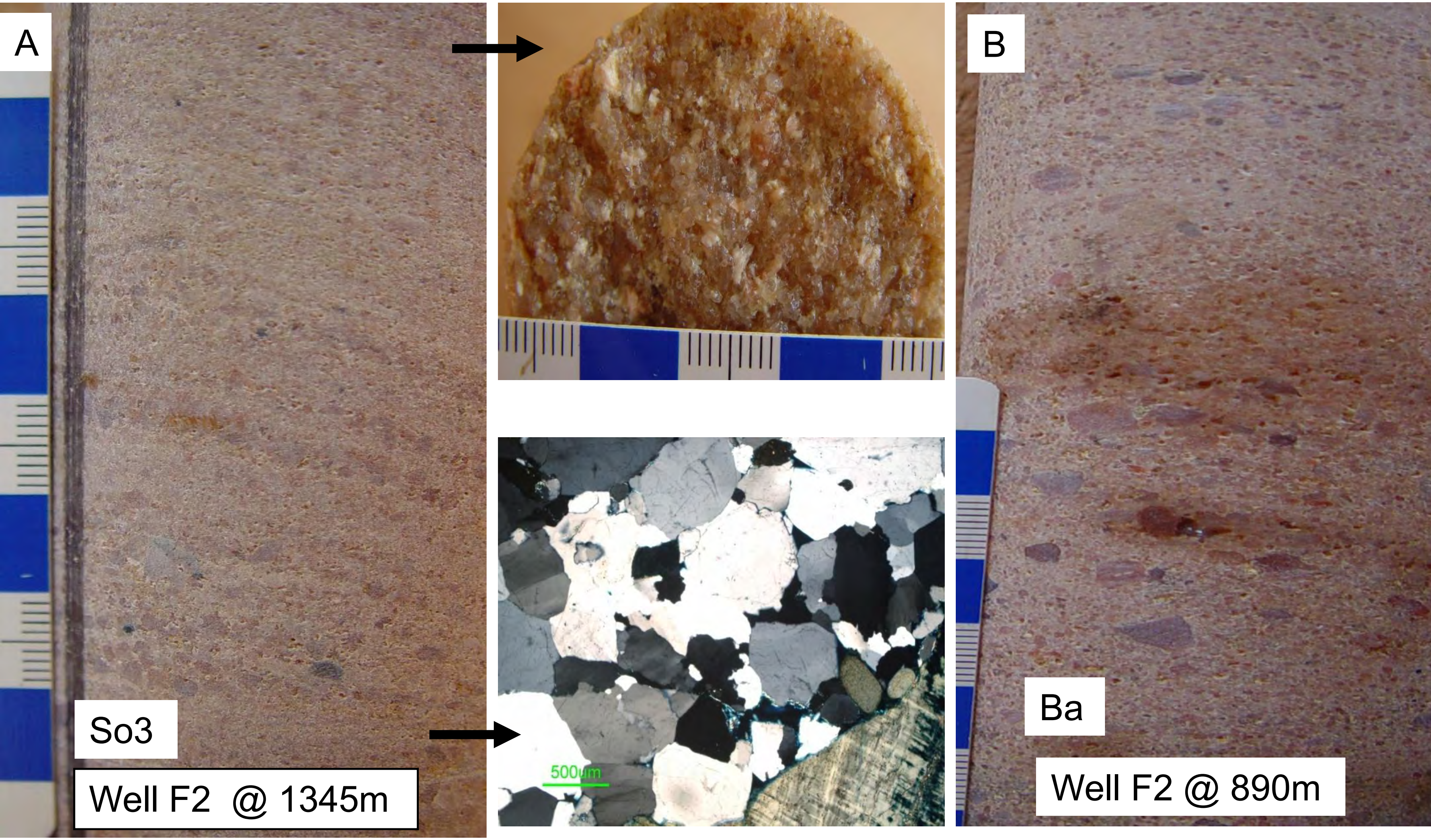


Fig. 14. Microphotograph of fine grained sandstone

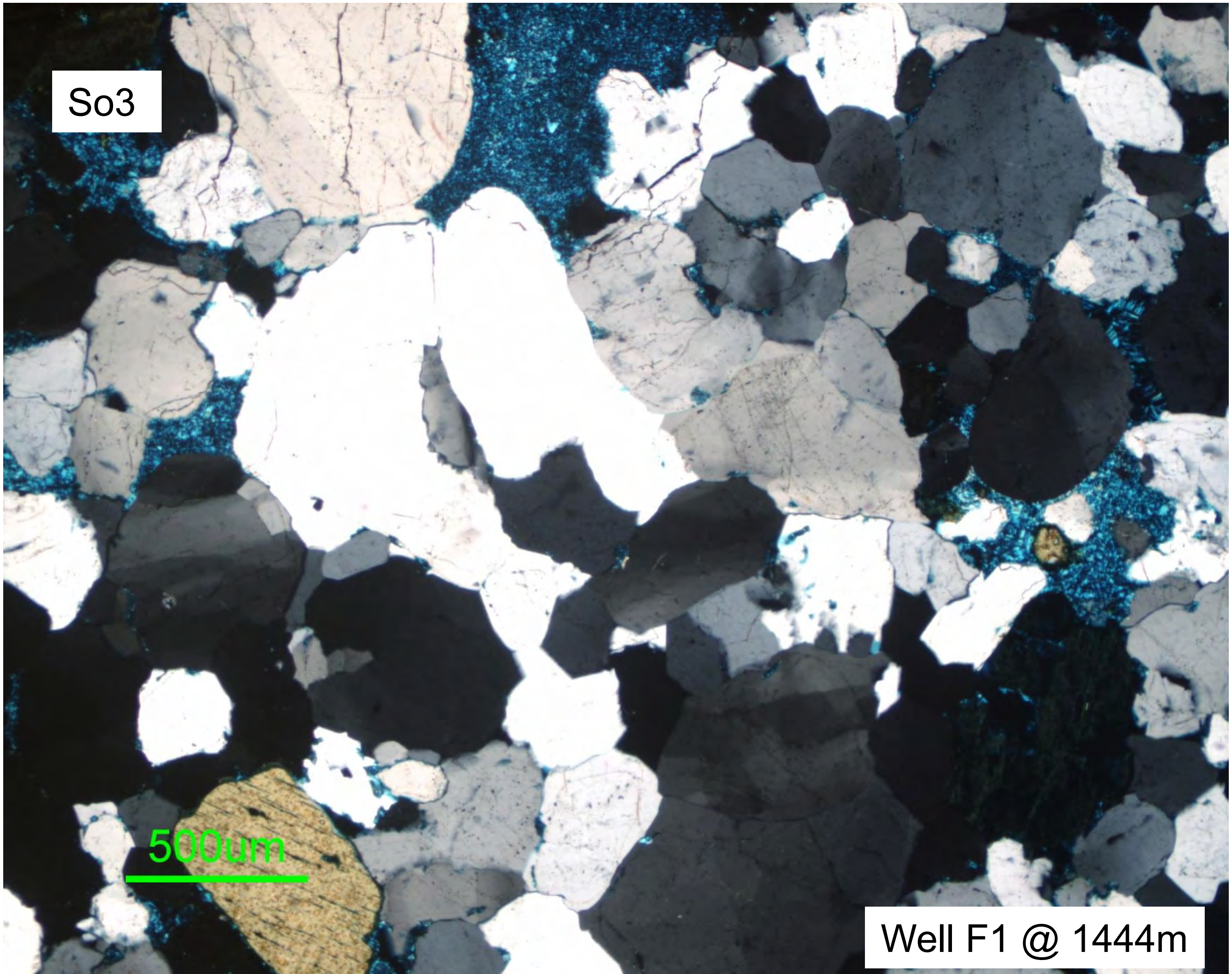


Fig. 15. Microphotograph medium grained sandstone

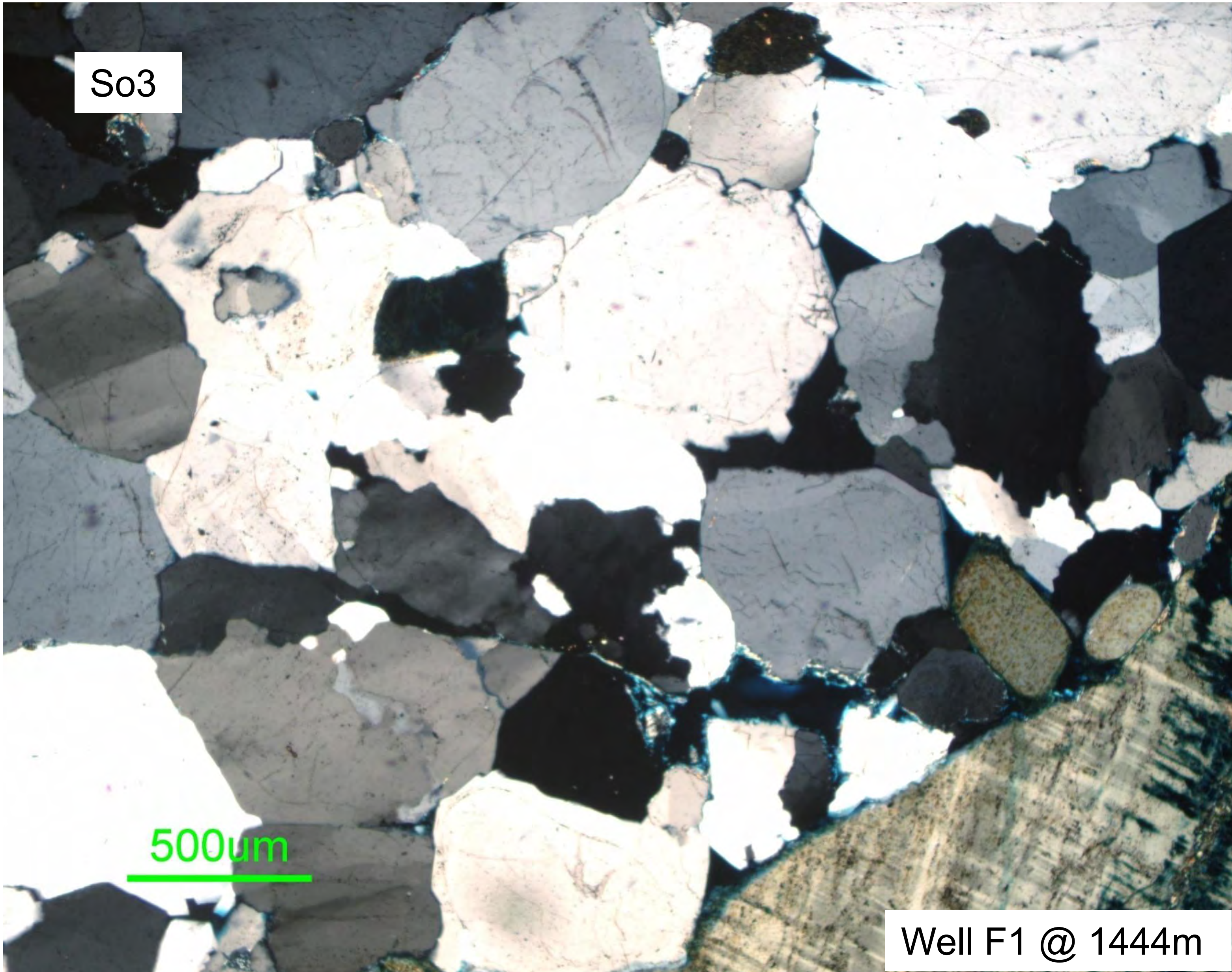


Fig. 16. Microphotograph of fine grained sandstone

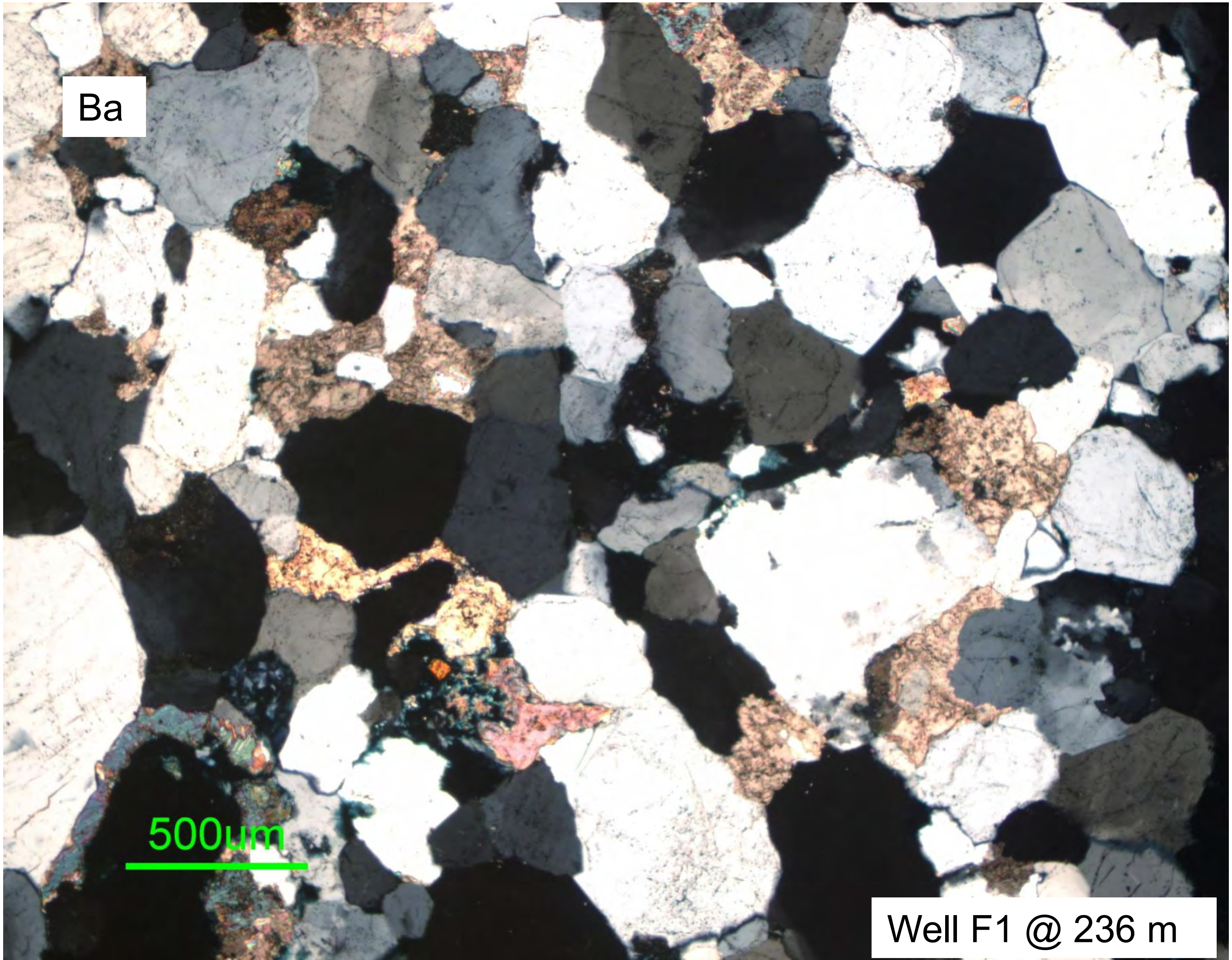
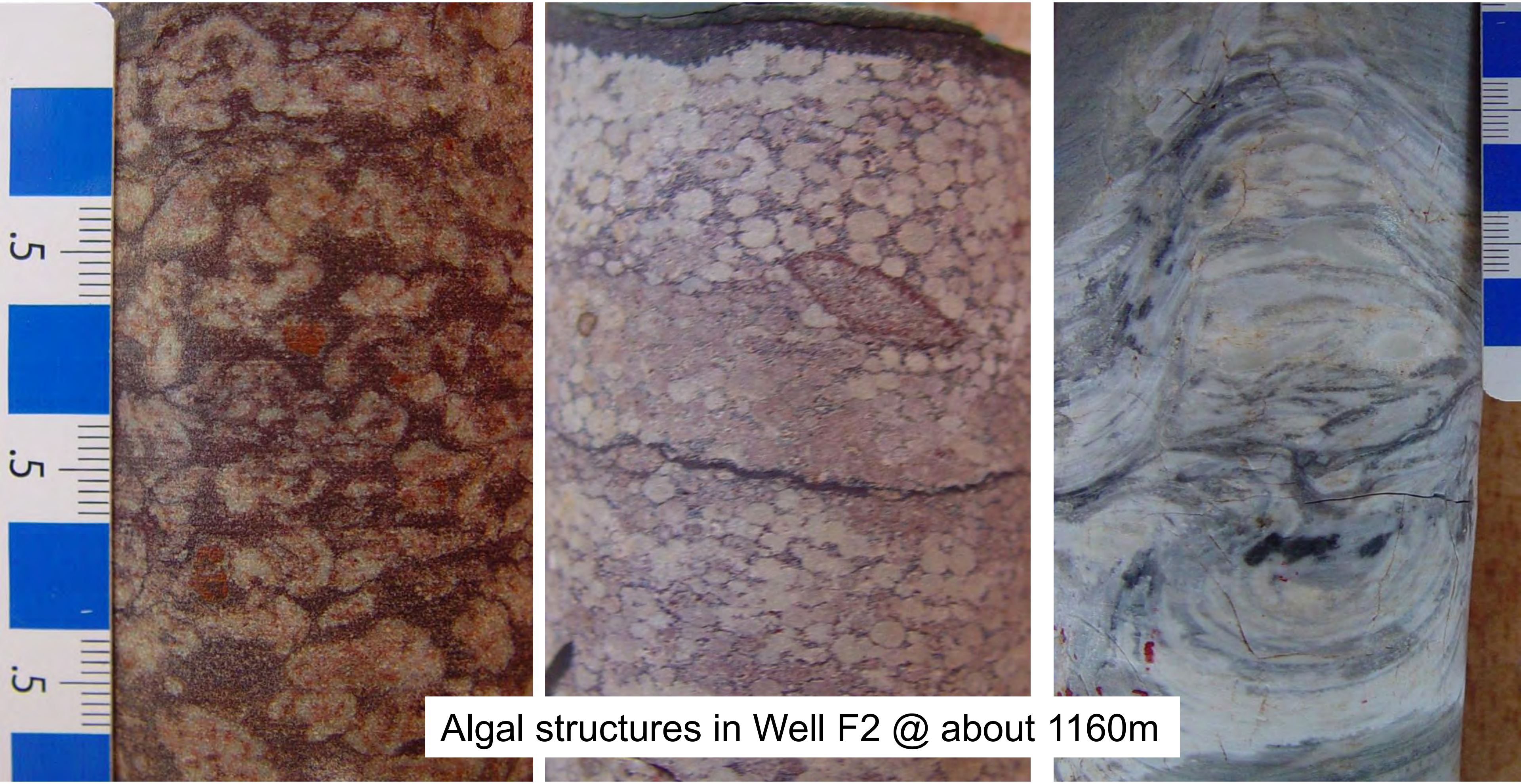


Fig. 17. Core of the black shale interval (F1 at 1311-1315m)

Fig. 18. Algal structures related to subaerial unconformity (At top of the So/Ba)



Algal structures in Well F2 @ about 1160m

Fig. 19. Microphotograph of the dolerite-diorite (So)

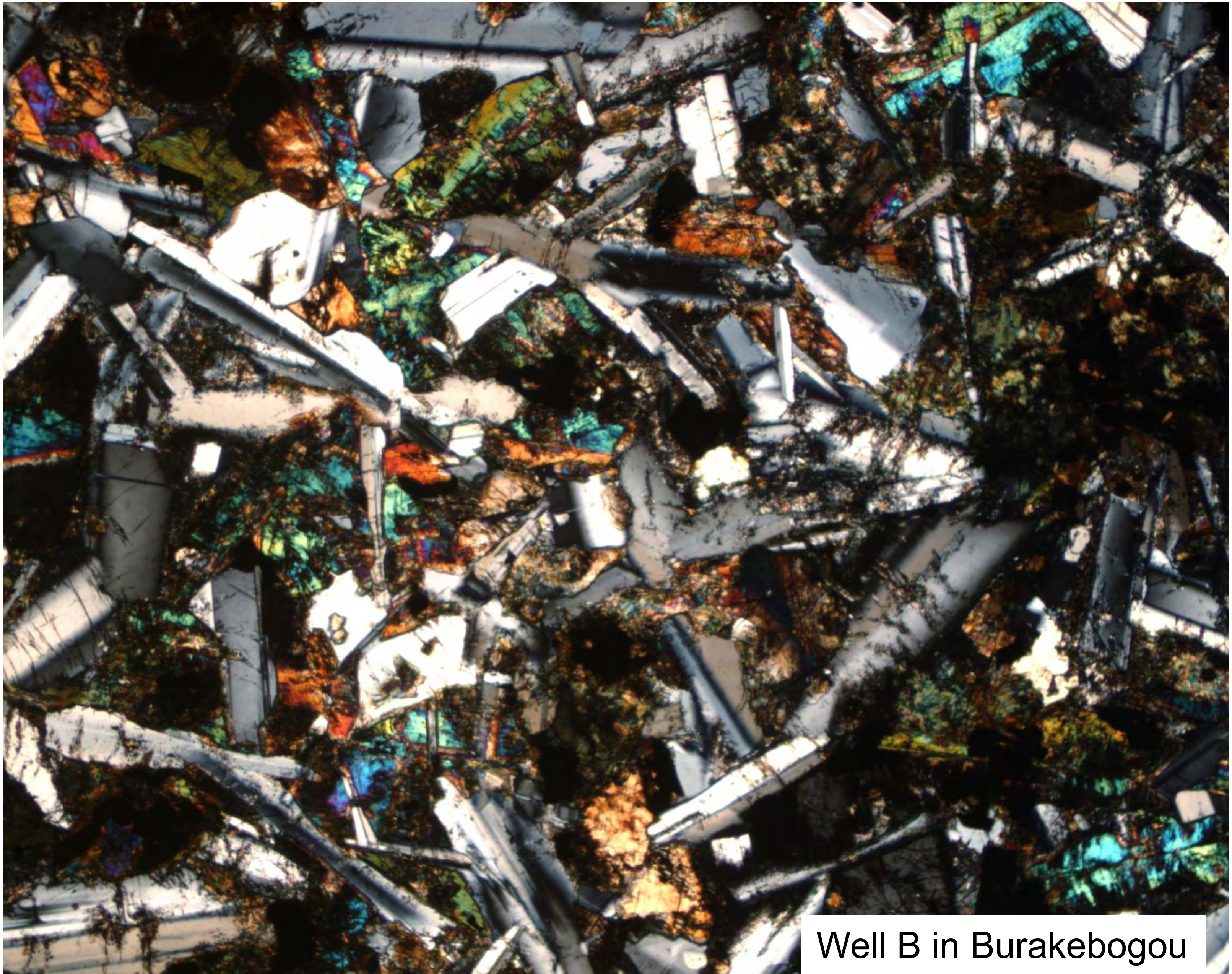
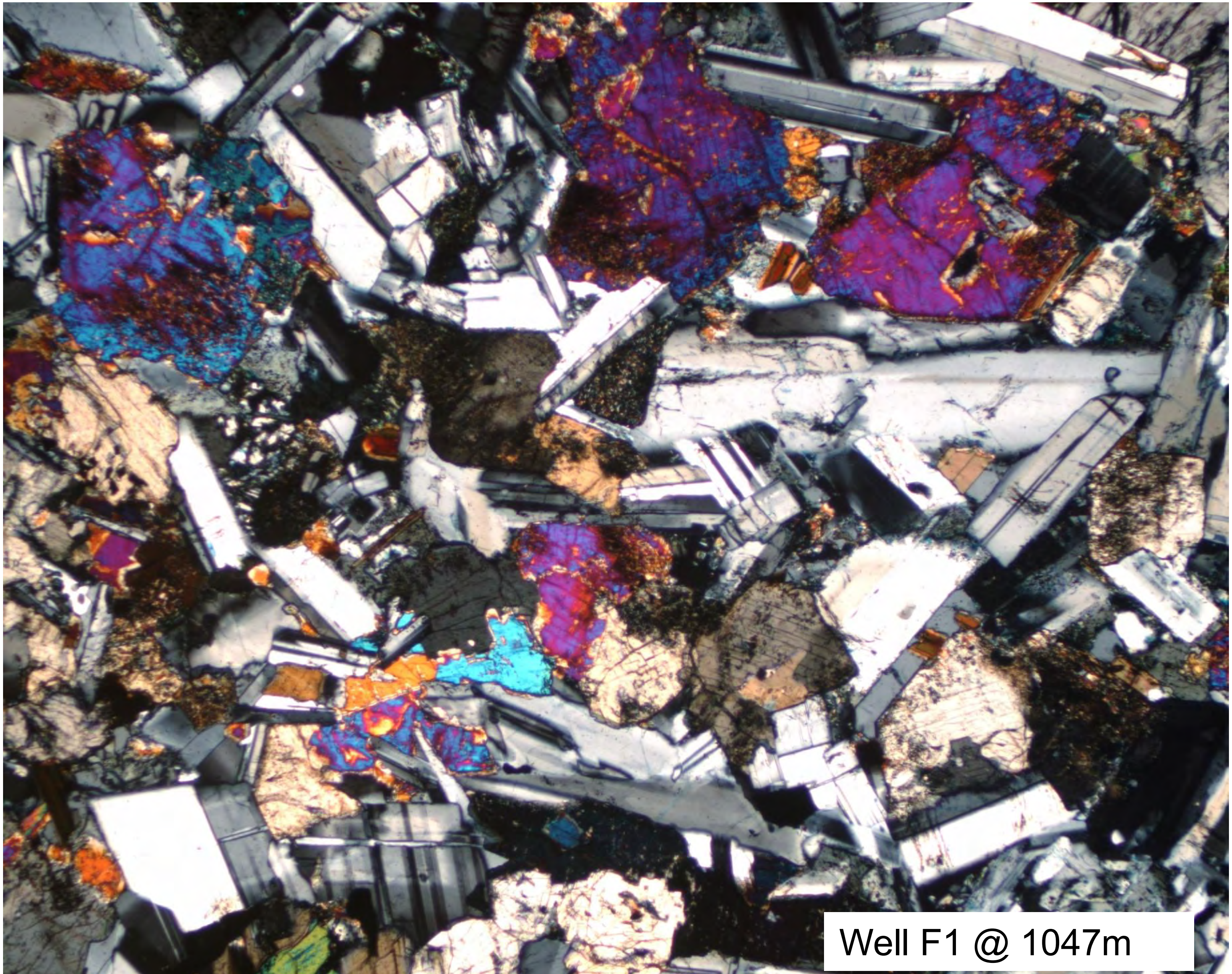
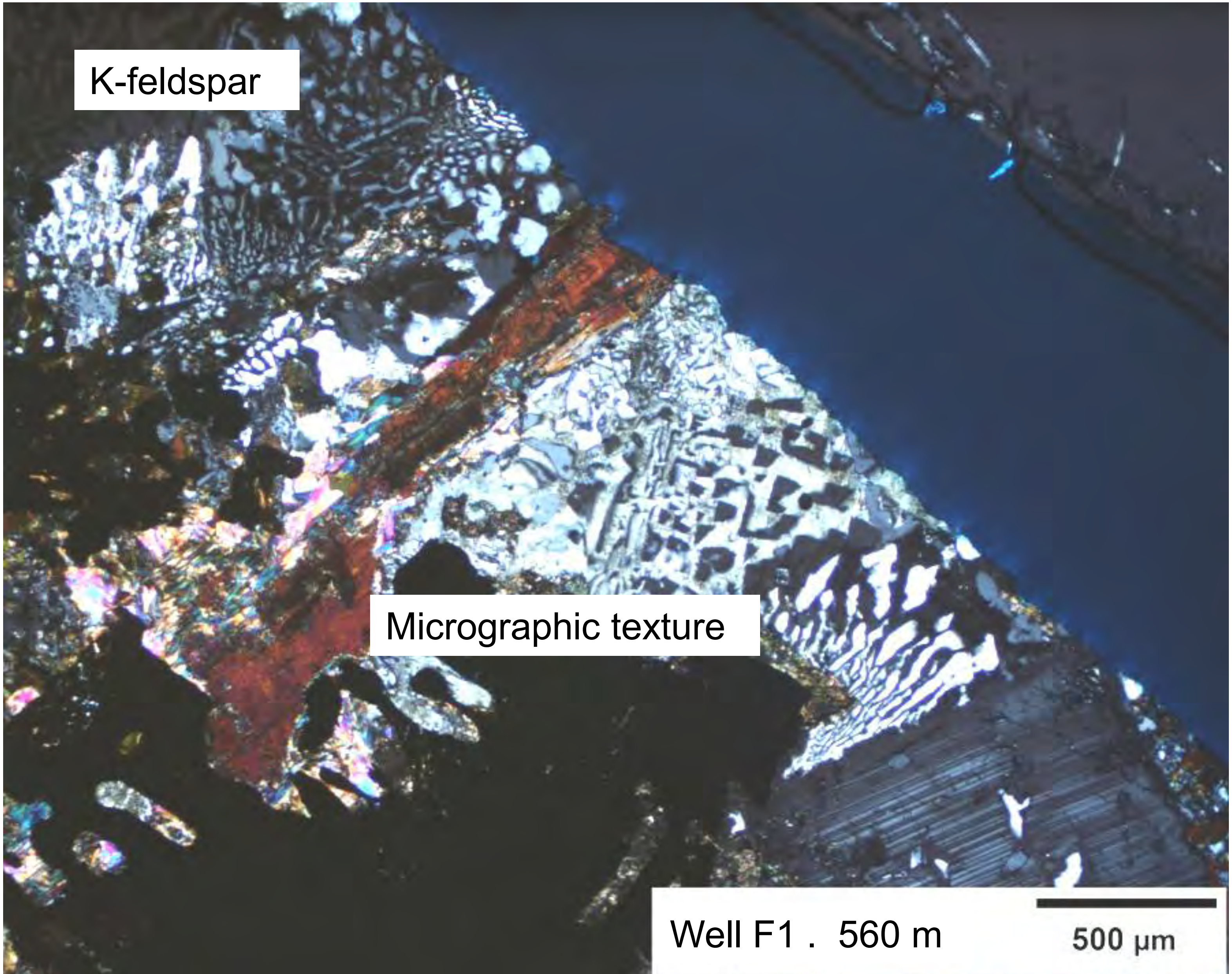


Fig. 20. Microphotograph of the dolerite-diorite (Ba)




K-feldspar
Micrographic texture
Well F1 . 560 m
500 µm