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Geological logging of drill cores from borehole KH-08-12 at Åknes, Møre & Romsdal, Western Norway

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REPORT

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Geological logging of drill cores from borehole KH-08-12 at Åknes, Møre & Romsdal, Western Norway

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Summary:

The borehole KH-08-12 was drilled in August/September 2012 by Geo Drilling and the logging was executed in March 2013 by the Geological Survey of Norway (NGU). The borehole is located at WGS-84 6895850N 395400E zone 32W and ca. 735 meters above sea level, at the upper western part of the Åknes rock slope. The drill cores are logged with regards to bedrock type, fracture frequency and zones of interest with respect to sliding plane(s). All drill cores are photographed, first dry and then wet, and are documents with pictures and detailed logging in this report.

The bedrock has gneissic structure with pervasive foliation throughout the ca. 200 m deep drill core. In general the foliation has sub-horizontal orientation, but is in some parts of the core strongly foliated. The bedrock consists of three main types; granitic gneiss, fine to coarse grained quarts dioritic gneiss and amphibolitic gneiss. In general the bedrock is rich on mica, dominated by biotite in the granitic and dioritic gneiss while chlorite dominates in the amphibolitic gneiss. From ca. 2 m to ca. 100 m the bedrock is mainly banded granitic gneiss that at parts has very high content of mica or changes to dioritic gneiss, also rich on mica (biotite). From 100 m to 134 m the bedrock is mainly dioritic gneiss with bands of granitic gneiss. From ca. 134 m to 202 m the bedrock consists mainly of banded amphibolitic gneiss, where dioritic gneiss comes in bands with varying width. The transitions between the different bedrock types are gradual, often with increasing (or decreasing) content of mica.

Three zones that contain clay are observed at ca. 60.77 m a clay zone of 2-3 cm, 1-2 cm at ca. 63.15 m and ca. 1 cm clay at ca. 78.50 m. In the two first zones the clay occurs in combination with a zone of crushed rock, whereas the last zone of clay occurs along a fracture. It is assumed that the widest clay zone at ca. 60.77 m is the zone that absorbs most movement and can be described as a sliding plane. This zone has the thickest and most well developed clay, containing mainly fine grained particles. In addition to the clay zones there are several zones of crushed rock from 60-72.66 m indicating the most unstable part of the rock mass. More unexpected is the ca. 22 cm wide zone of crushed rock at 150.75-151 meter, where the rock mass is intensely fractures in an otherwise competent bedrock of amphibolitic gneiss.

It is the upper 80 m that has the highest fracture frequency, including both crushed zones and actual fractures. There are a few parts with core loss, at the top with ca. 2.20 m and ca. 1.10 m at 18.6 to 19.70 m. The fractures are dominated by foliation parallel fractures throughout the core. In the log the actual fractures occurring in addition to crushed zones and core loss is registered. Fractures that are obviously produced by the drilling are also registered, probably in a conservative manner and the number of drilling produced fractures are high throughout the drill core. Where vertical fractures occur the bedrock is prone to fracturing, commonly drilling produced fractures, that increases the fracture frequency without reducing the rock quality.

Keywords: Core logging	Borehole	Rock slope

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1. INTRODUCTION

The borehole KH-08-12 was drilled in August/September 2012 by Geo Drilling and the logging was executed in March 2013 by the Geological Survey of Norway (NGU). A student at Norwegian University of Science and Technology (NTNU) joined the logging to carry out engineering geological parameters that are to be used in his Master of Science thesis.

The borehole is located at WGS-84 6895850N 395400E zone 32W and ca. 735 meter above sea level, at the upper western part of the Åknes rock slope. The drill cores are logged with regards to bedrock type, fracture frequency and zones of interest with respect to sliding plane(s). All drill cores are photographed, first dry and then wet, and are documented with pictures and detailed description in this report (Figure 9 to Figure 42).

2. GEOLOGICAL CORE LOGGING

The bedrock has gneissic structure with pervasive foliation throughout the ca. 200 meter deep drill core. In general the foliation has sub-horizontal orientation, but is in some parts of the core strongly foliated (Figure 1). Folded foliation is described in the log below. The bedrock consists of three main types; granitic gneiss, fine to coarse grained quarts dioritic gneiss and amphibolitic gneiss. In parts the granitic gneiss has augen structure, with augen from 0.5 cm and up to 3 cm clasts (Figure 2). In general the bedrock is rich on mica, dominated by biotite in the granitic and dioritic gneiss while chlorite dominates in the amphibolitic gneiss. Locally the bedrock can consists of close to 100% mica, commented on in the log.

Figure 1. Example of folded foliation, here at 132-132.40 m.

From ca. 2 meter to ca. 100 meter the bedrock is mainly banded granitic gneiss that at parts has very high content of mica or changes to dioritic gneiss, also rich on mica (biotite). Between 100 meter and 134 meter the bedrock is mainly dioritic gneiss with bands of granitic gneiss. From ca. 134 meter to 202 meter the bedrock consists mainly of banded amphibolitic gneiss, where dioritic gneiss comes in bands with varying width. The transition between the different bedrock types is gradual, often with increasing (or decreasing) content of mica. A detailed description of the bedrock types and occurrence is given in Table 1.

Figure 2. Example of augen structure in granitic gneiss, here at 4.25-4.37 m.

Table 1. Detailed description of log with emphasis on bedrock type and variation in bedrock.

Depth (m)	Bedrock type	Description
0-2.20		Core loss ca. 2.2 m
2.20-2.80	Granitic gneiss	Banded granitic gneiss
2.80-7.66	Granitic gneiss	Banded with tendency of augen structure
7.66-9.98	Granitic gneiss	Banded granitic gneiss dominated dark bands of biotite, that contain K-feldspar
9.18-12.08	Granitic gneiss	Narrow bands with augen structure
12.08-13.80	Granitic gneiss	Banded granitic gneiss dominated dark bands of biotite, that contain K-feldspar
13.80-16.05	Granitic gneiss	Finely bands with slight augen structure
16.05-18.25	Granitic gneiss	Banded granitic gneiss dominated dark bands of biotite, that contain K-feldspar
18.55-1965		Core loss ca. 1.1 m
18.25-29.20	Granitic gneiss	Finely banded gneiss with augen structure. Bands with biotite varying thickness
29.20-50.05	Dioritic gneiss	Rich on mica (biotite) and varying with bands of granitic gneiss
50.05-55.57	Granitic gneiss	Banded granitic gneiss with mm thick bands. Intruded pegmatite dikes, and bands of mica (biotite)
55.57-57.20	Diorite gneiss	Banded
57.20-60.05	Granitic gneiss	Banded granitic gneiss and folded foliation
60.05-61.30	Dioritic gneiss	
60.77	Clay zone	Clay zone 2-3 cm after ca. 10 cm crushed zone. NGU sample 074901
61.30-62.87	Granitic gneiss	Banded granitic gneiss

62.87-63.30	Dioritic gneiss	Crushed zone
63.15	Clay zone	Clay zone 1-2 cm before ca. 10 cm crushed zone
63.30-70.30	Granitic gneiss	Banded with increasing bands with biotite
70.30-81.70	Dioritic gneiss	Banded dioritic gneiss with bands of granitic gneiss 75-76 m folded foliation 77.10-77.60 m dominated by granitic gneiss 79.0-79.90 m dominated by granitic gneiss 80.65-81.45 m rich on biotite, highly fractured/crushed along mica-rich layers
78.50	Clay zone	Clay zone ca. 1 cm
81.70-87.10	Dioritic gneiss	Compact and competent dioritic gneiss that is less fractures than rock above.
87.10-90.45	Dioritic gneiss	Dioritic gneiss with mm wide bands of granitic gneiss, and folded foliation
90.45-100.30	Granitic gneiss	Banded granitic gneiss with augen structure with up to 3 cm clasts. 96.20-97 m dioritic gneiss
100.30-112	Dioritic gneiss	Dioritic gneiss with bands of granitic gneiss. 110.53-110.94 m granitic gneiss
112-114.20	Granitic gneiss	Fine grained granitic gneiss, with less distinct bands. Folded foliation. 113.07-113.38 m dioritic gneiss
114.20-119.75	Dioritic gneiss	Dioritic gneiss with pegmatite intrusions that are folded
119.75-123.95	Granitic gneiss	Banded granitic gneiss with wide bands
123.95-134.60	Dioritic gneiss	Dioritic gneiss with bands of granitic gneiss. 126.50-128.10 m dominated by granitic gneiss. 130-131 m dominated by bands of granitic gneiss 132-133 m folded foliation
134.60-162	Amphibolitic gneiss	Amphibolitic gneiss with varying content of chlorite 147.85-162 m rich on chlorite
162-202	Amphibolitic gneiss	Amphibolitic gneiss with a few bands of granitic gneiss. A band of ~100% chlorite at 164.10 m and 197.85-198.20 m

There is observed three zones that contain clay; at ca. 60.77 m a clay zone of 2-3 cm (Figure 3), at ca. 63.15 m a clay zone of 1-2 cm and at ca. 78.50 m a clay zone of ca. 1 cm (Figure 4). In the two first zones the clay occurs in combination with a zone of crushed rock, whereas the last zone of clay occurs along a fracture. It is assumed that the widest clay zone at ca. 60.77 m is the zone that absorbs most movement and can be described as a sliding plane. This zone has the thickest and most well developed clay, containing mainly fine grained particles.

In addition to the clay zones there are several zones of crushed rock from 60 m to 72.66 m (Figure 17, Figure 18 and Figure 19), indicating the most unstable part of the rock mass. More unexpected is the ca. 22 cm wide zone of crushed rock at 150.75-151 meter, where the rock is intensely fractured in an otherwise competent bedrock of amphibolitic gneiss with good rock quality (Figure 32).

Figure 3. Clay zone at ca. 60.77 with 2-3 cm thickness. This clay zone is located at end of a ca. 10 cm zone of crushed rock. The clay is well developed and mainly contains fine grained material, therefore this zone is regarded as the main zone of movement, and is possibly a sliding plane.

Figure 4. Clay zones at ca. 63.15 m and 78.50 m. The first is 1-2 cm thick and in combination with a zone of crushed rock, while the latter is ~1 cm thick and along a fracture.

Highly fractured zones or zones of crushed rock frequently occur in parts of the bedrock with high mica content (Figure 5). Hence, an increase in mica content makes the bedrock prone to fracturing.

Figure 5. The mica (biotite) rich zones are prone to fracturing (crushing) as seen at ca. 80.65 m.

Several fractures (narrow zones) have rusty colour that indicate water flow. As shown in Figure 6 the material show iron precipitation that is common where ground water circulate.

Figure 6. Narrow zone of crushed rock that has rusty colour at ca. 167.35 m, indicating water flow along the fracture/zone.

It is the upper 80 meters that has the highest fracture frequency, including both crushed zones and actual fractures (Figure 7). There are a few parts with core loss, at the top with ca. 2.20 meter and ca. 1.10 meter at 18.55 to 19.65 meter. The fractures are dominated by foliation parallel fractures throughout the core, as sees in Figure 7.

In the log, the actual fractures occurring in addition to crushed zones and core loss is registered (Figure 7). Fractures that are obviously produced by the drilling are also registered, probably in a conservative manner and the number of drilling produced fractures are high throughout the drill core (Figure 8). Several of the foliation parallel fractures are probably also produced due to the drilling process, but they are not easy to distinguish from true foliation parallel fractures since they commonly exploit weak mica layers in the bedrock. Where vertical fractures occur, the bedrock is prone to fracturing, commonly drilling produced fractures, that increases the fracture frequency without reducing the rock quality (Figure 8).

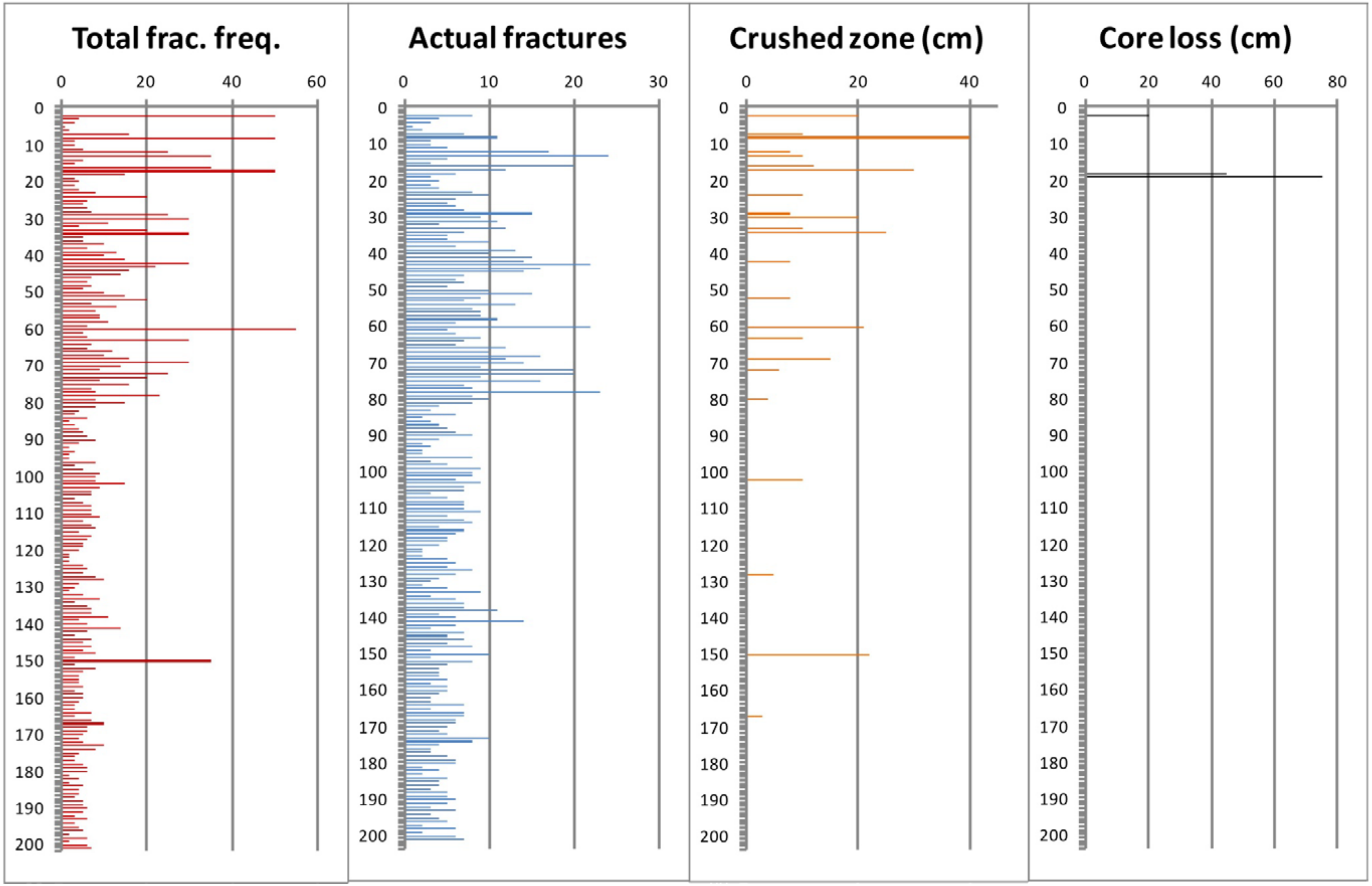

Figure 7. Graphs from core logging with total fracture frequency including fractures and crushed zones (left), actual fractures observed, crushed zones with length given in cm and core loss given in cm to the right.

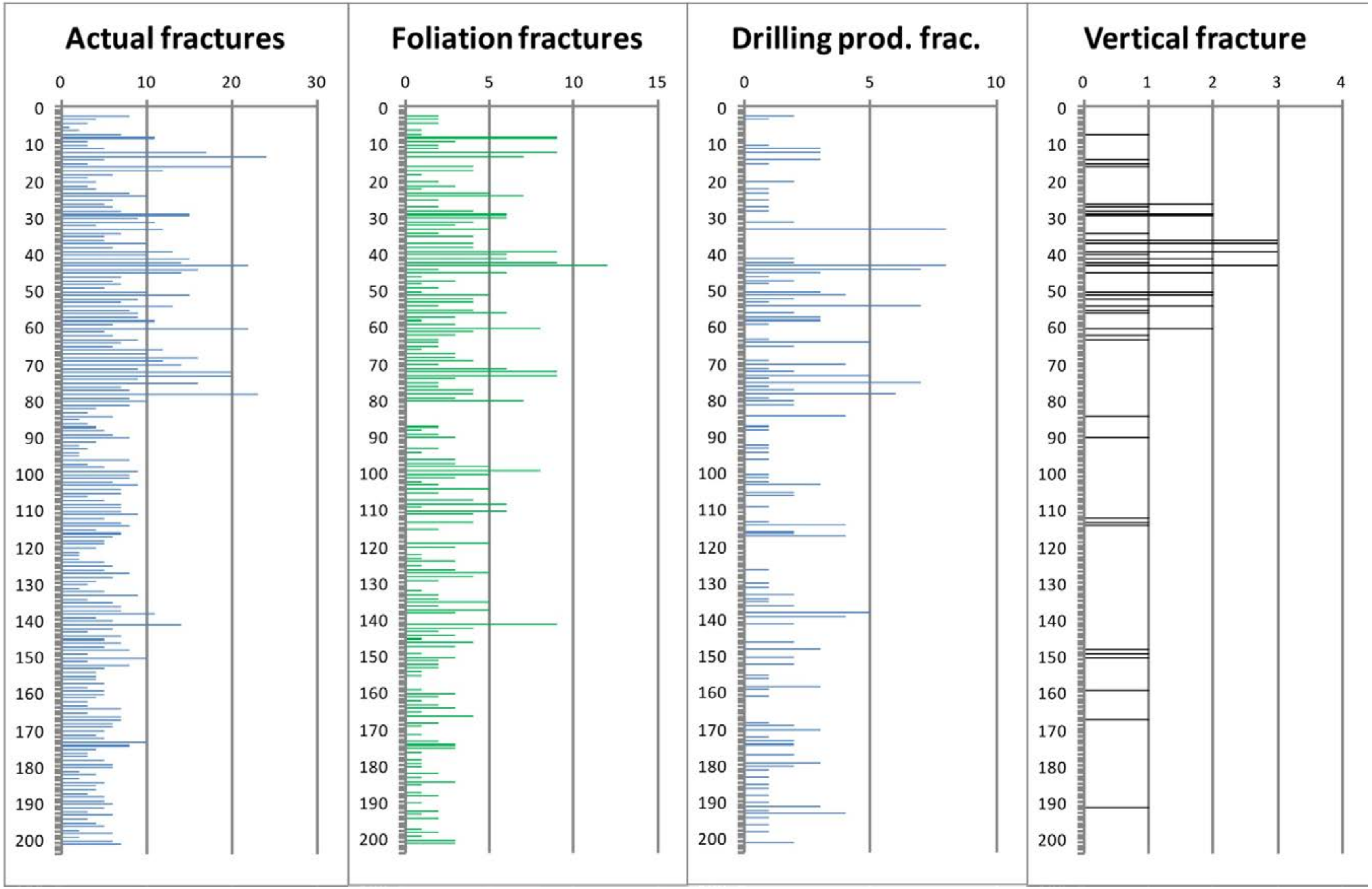

Figure 8. Graphs from core logging with actual fractures observed (left), of those fractures are foliation fractures, drilling produced fractures and vertical fractures (right) registered.

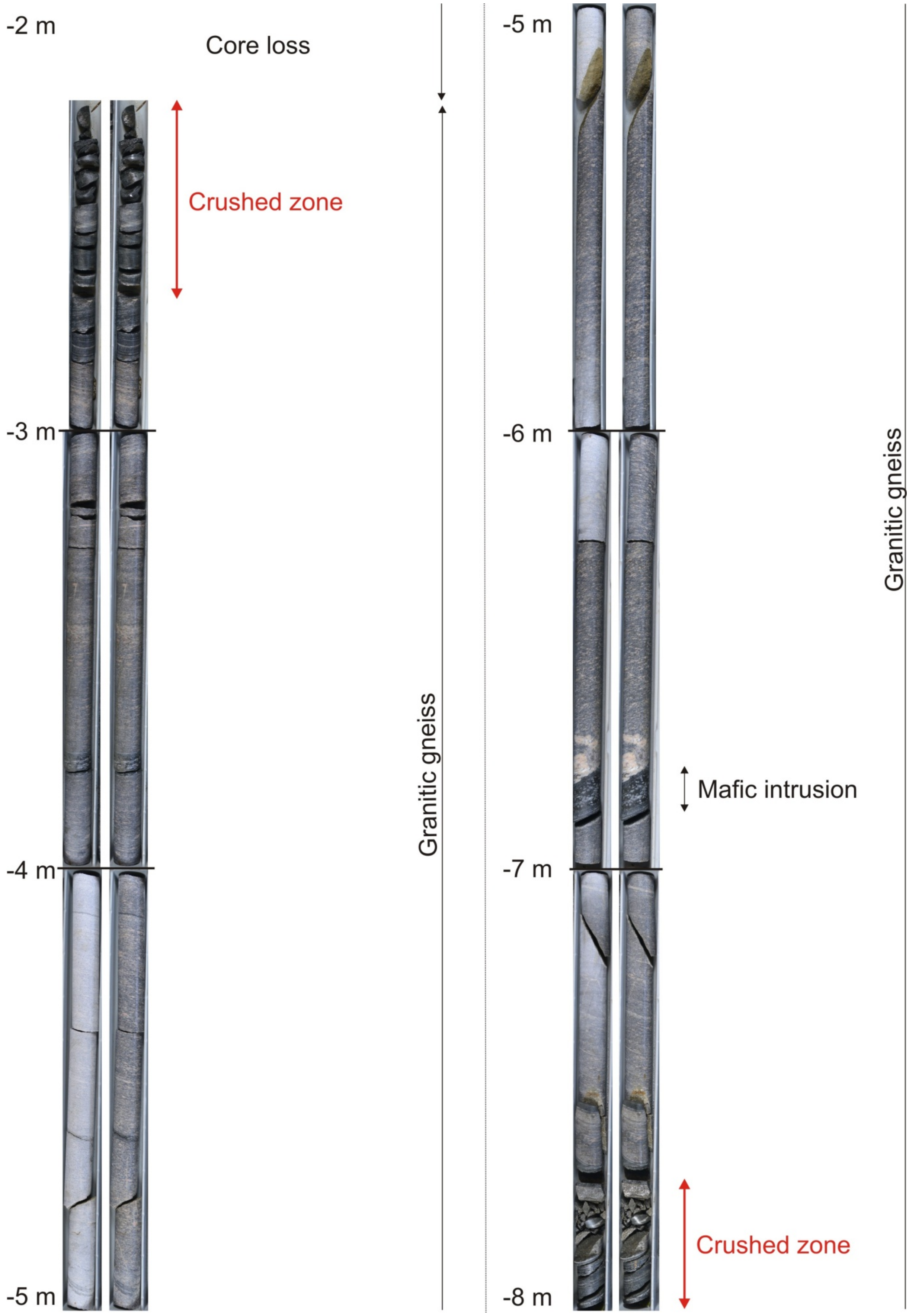

Figure 9. Geological core logging from ca. 2 to 8 m depth with pictures of the dry (left) and wet (right) core.

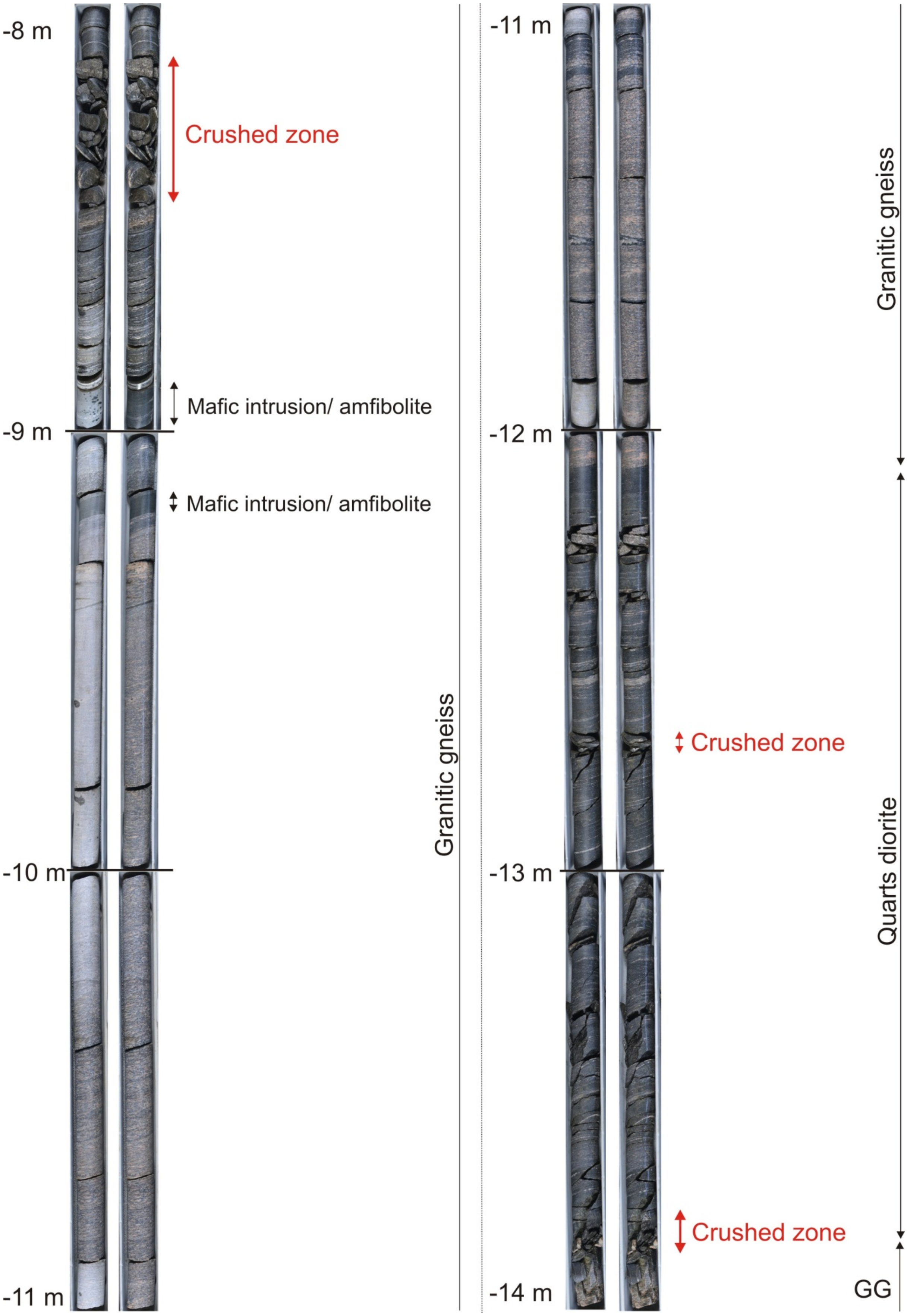

Figure 10. Geological core logging from 8 to 14 m depth with pictures of the dry (left) and wet (right) core.

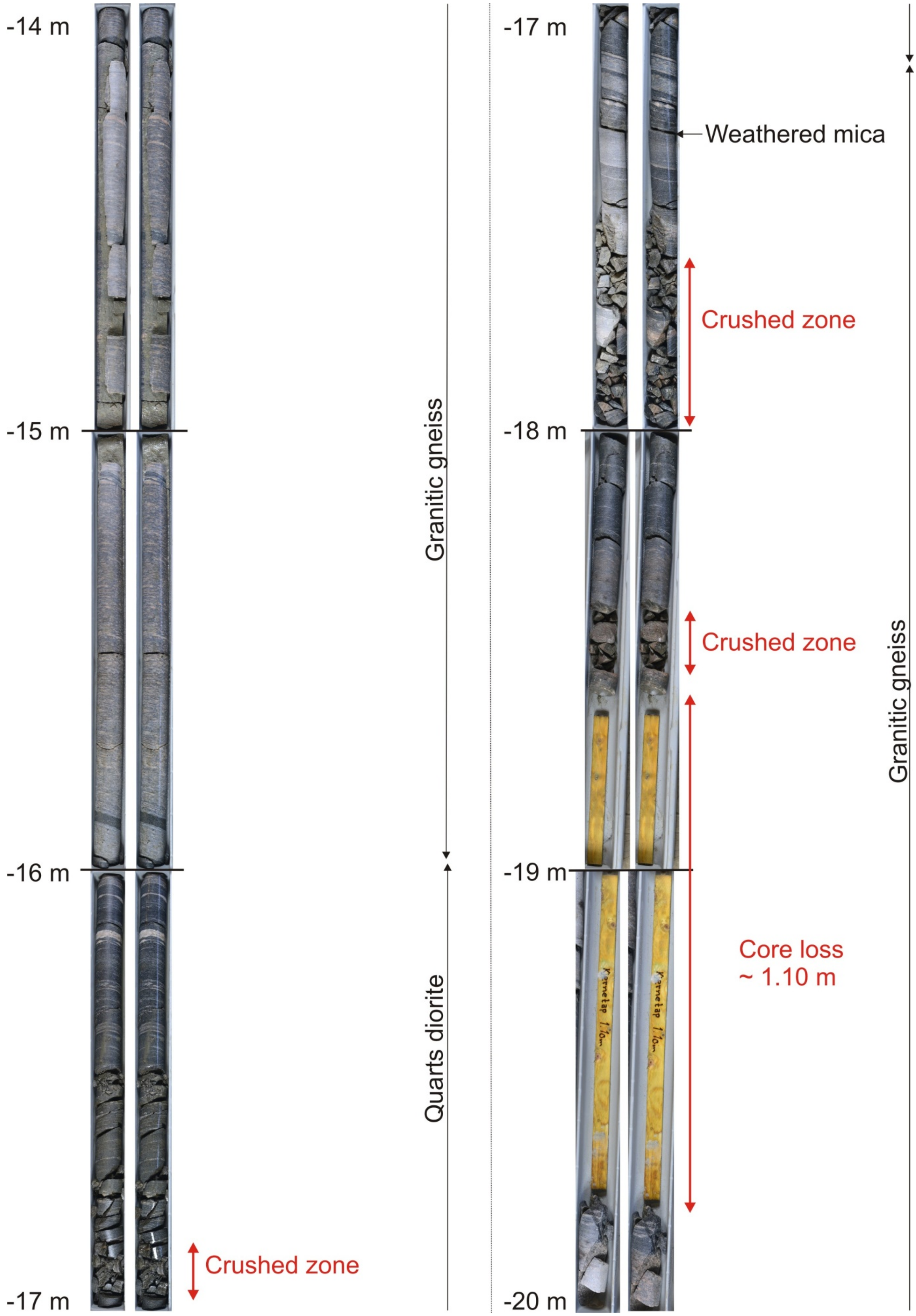

Figure 11. Geological core logging from 14 to 20 m depth with pictures of the dry (left) and wet (right) core.

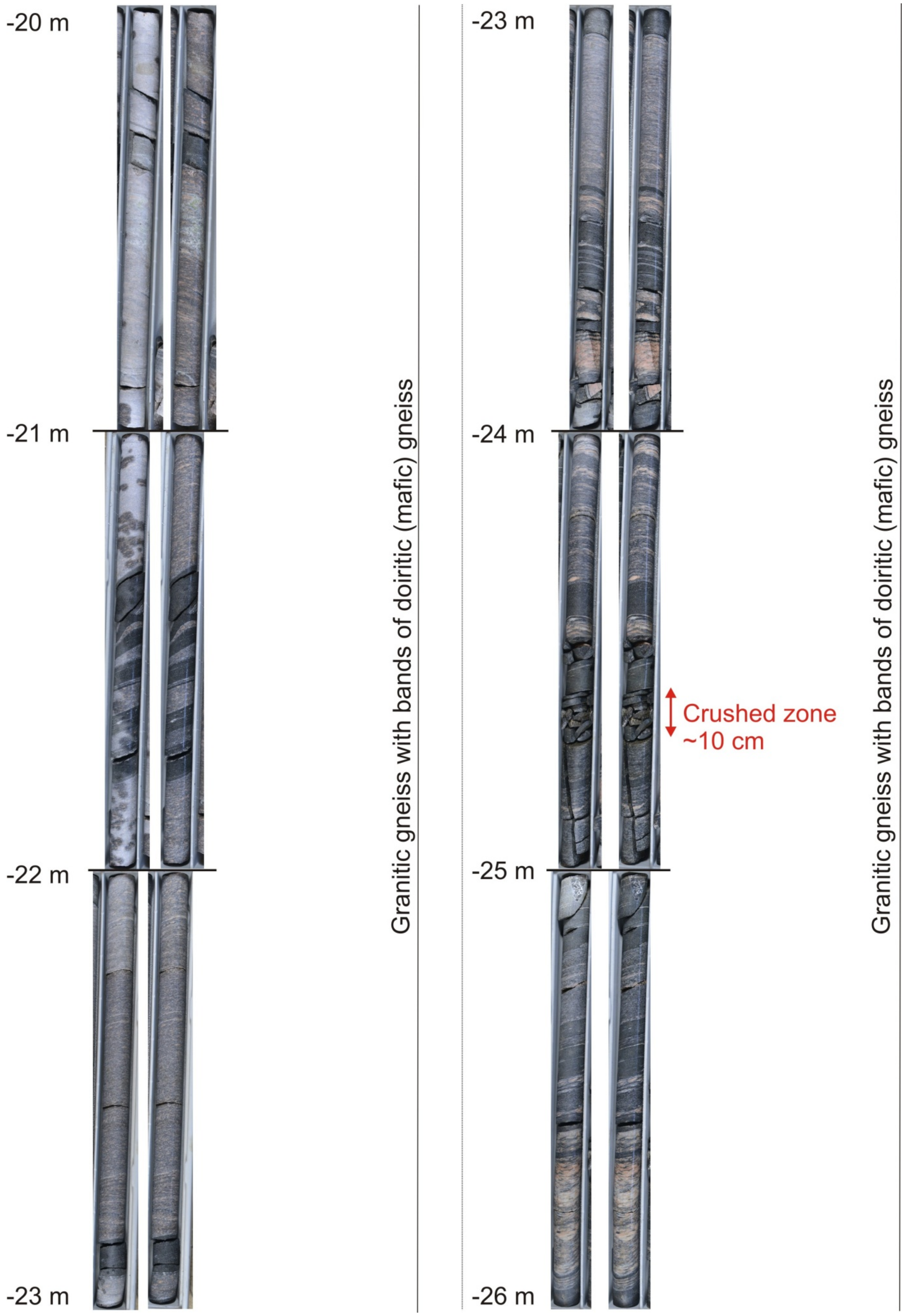

Figure 12. Geological core logging from 20 to 26 m depth with pictures of the dry (left) and wet (right) core.

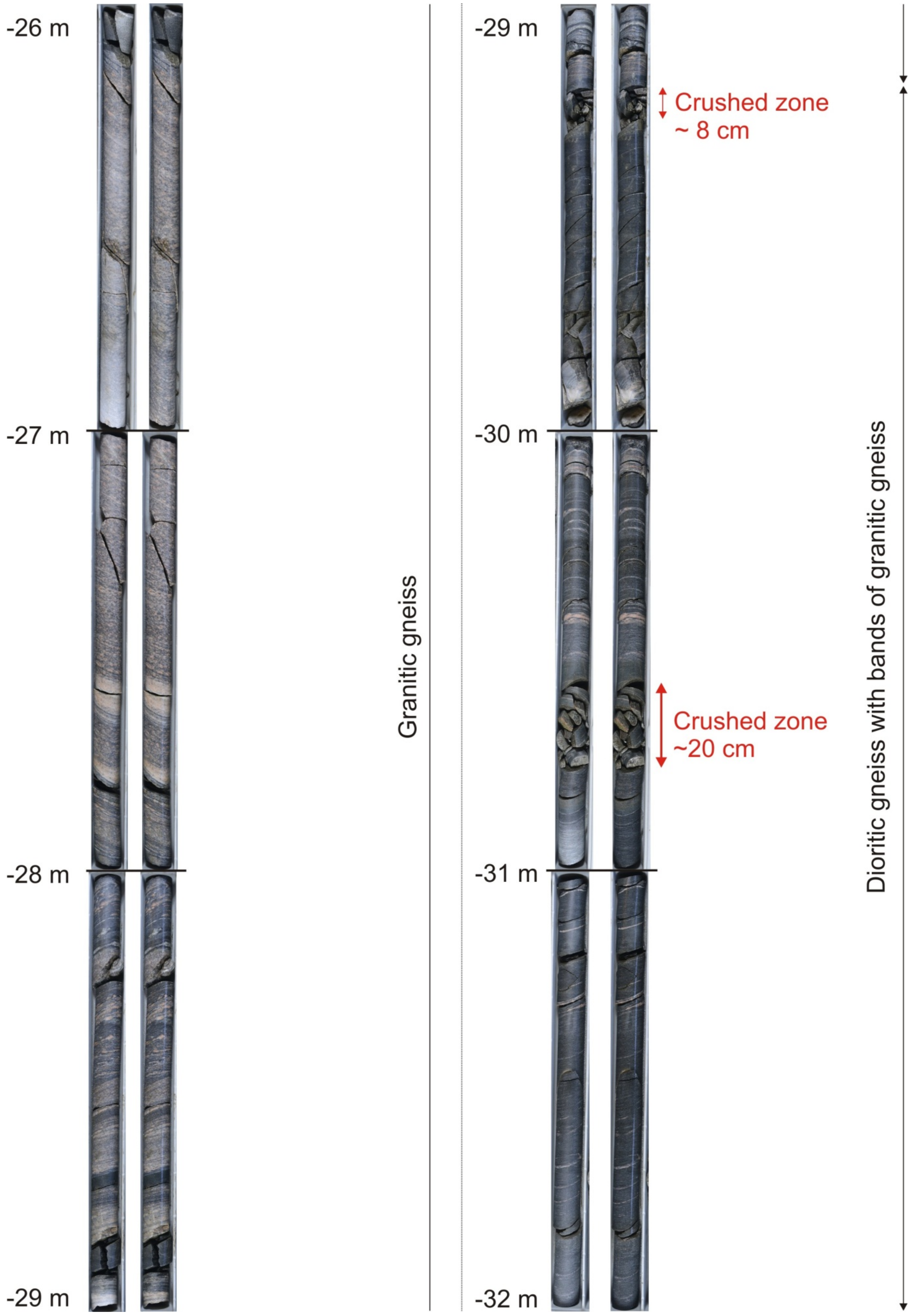

Figure 13. Geological core logging from 26 to 32 m depth with pictures of the dry (left) and wet (right) core.

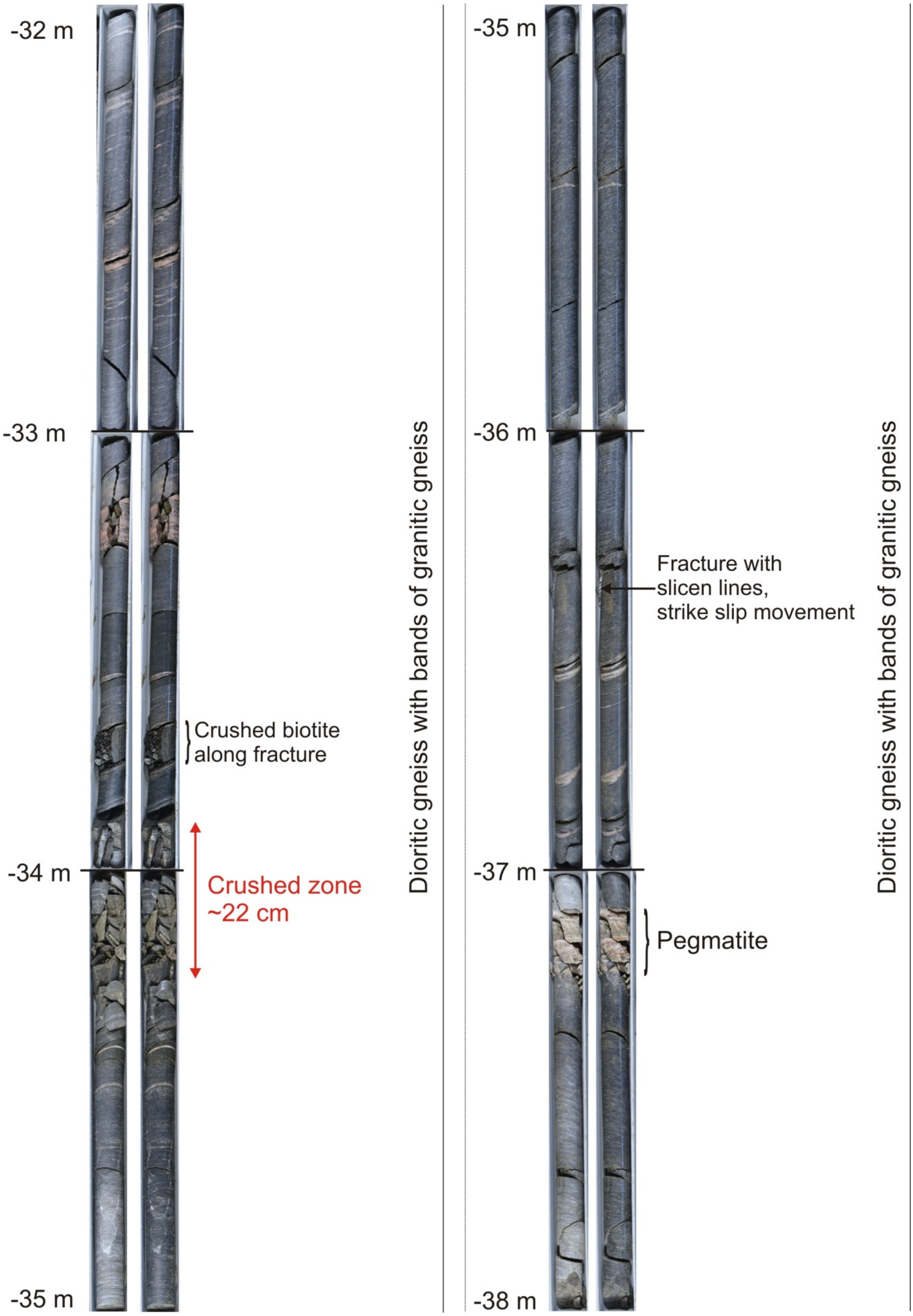

Figure 14. Geological core logging from 32 to 38 m depth with pictures of the dry (left) and wet (right) core.

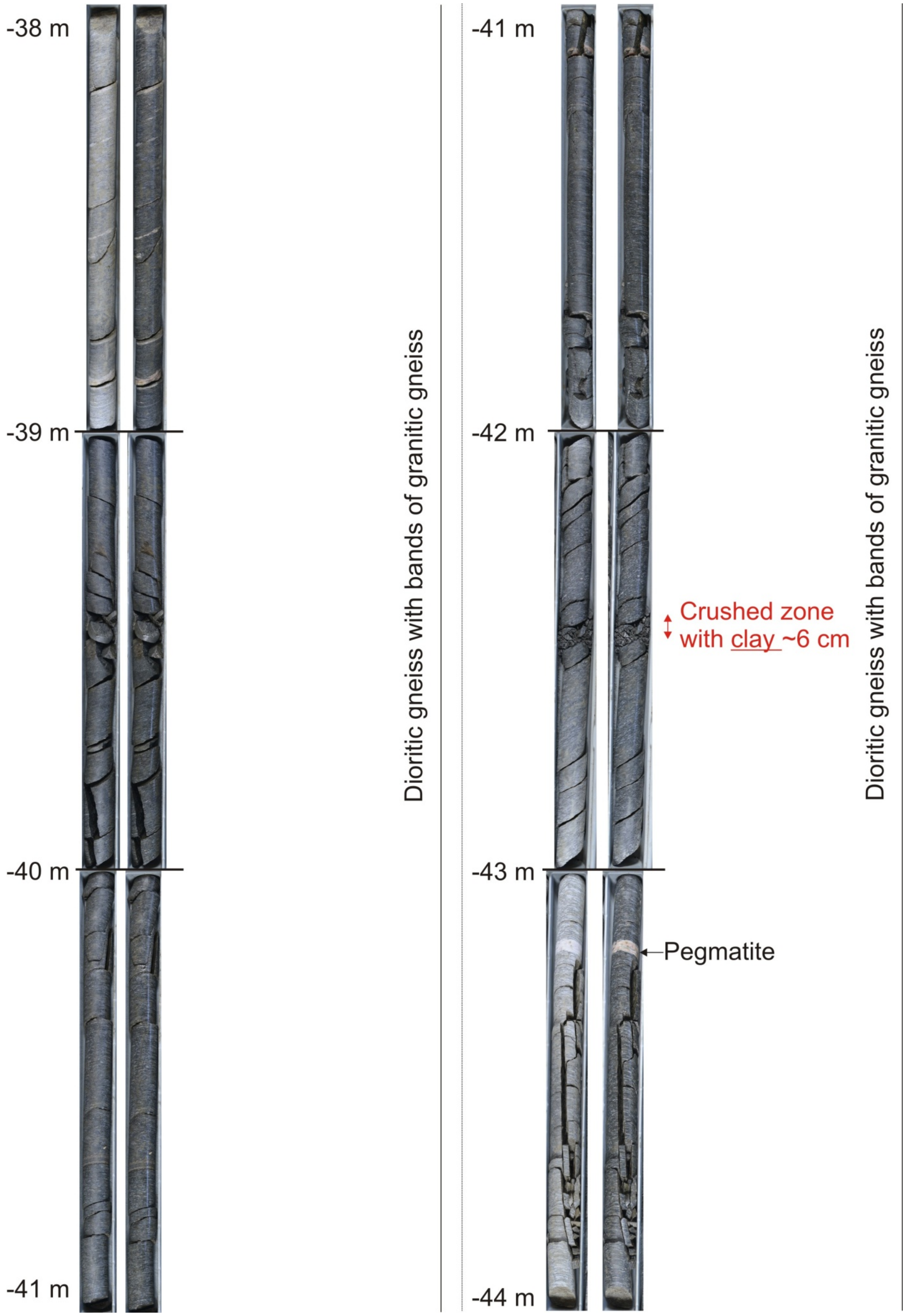

Figure 15. Geological core logging from 38 to 44 m depth with pictures of the dry (left) and wet (right) core.

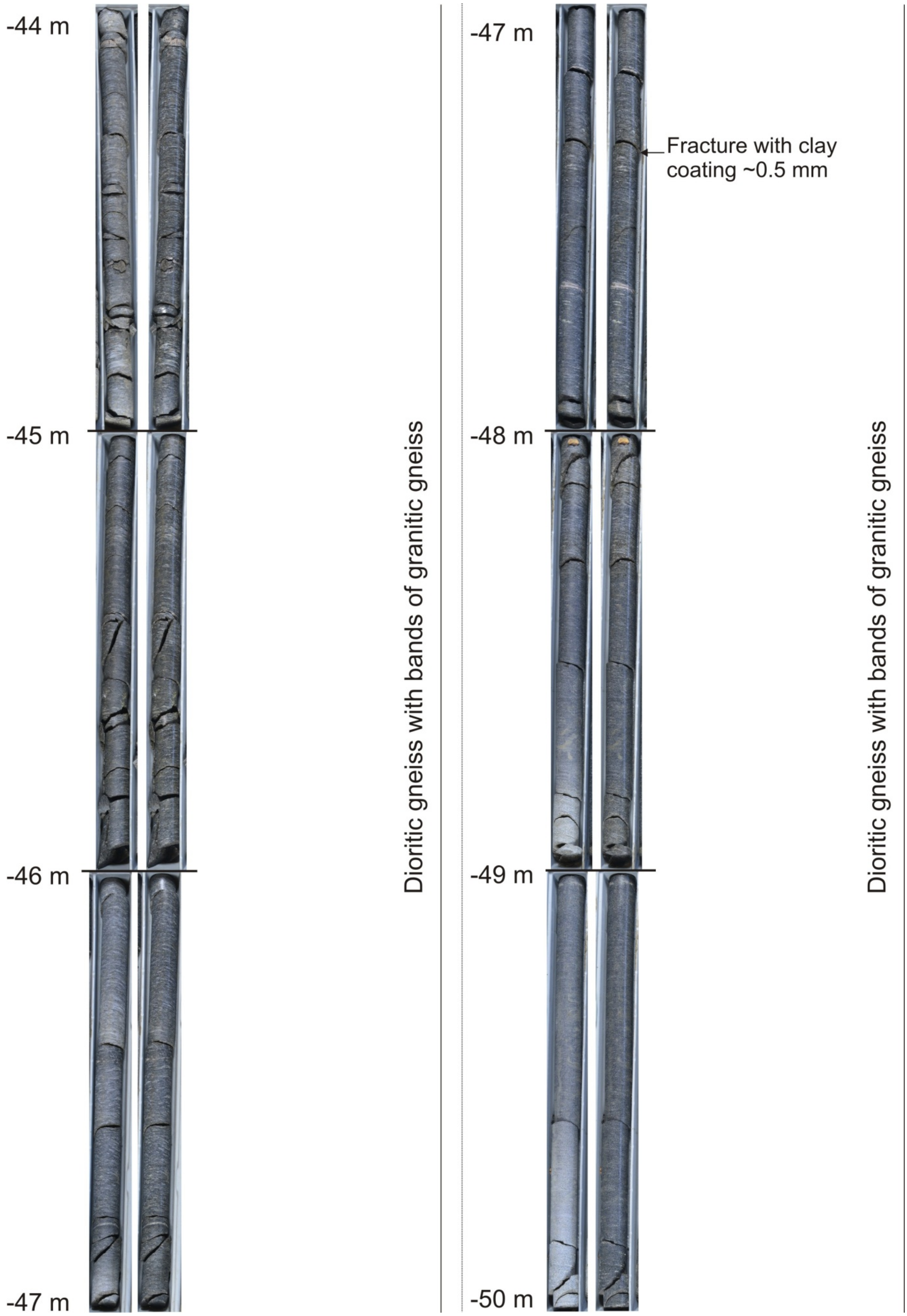

Figure 16. Geological core logging from 44 to 50 m depth with pictures of the dry (left) and wet (right) core.

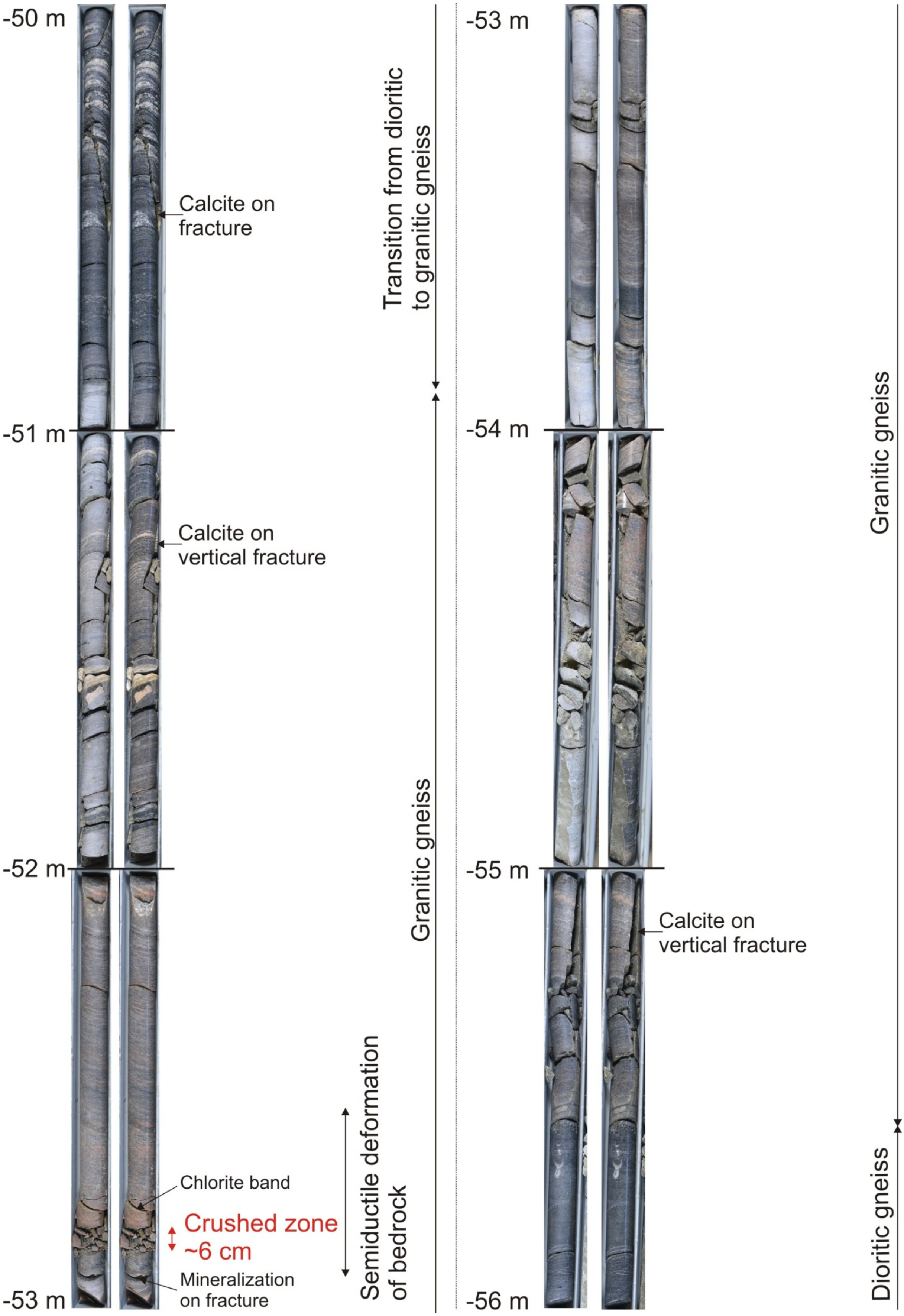

Figure 17. Geological core logging from 50 to 56 m depth with pictures of the dry (left) and wet (right) core.

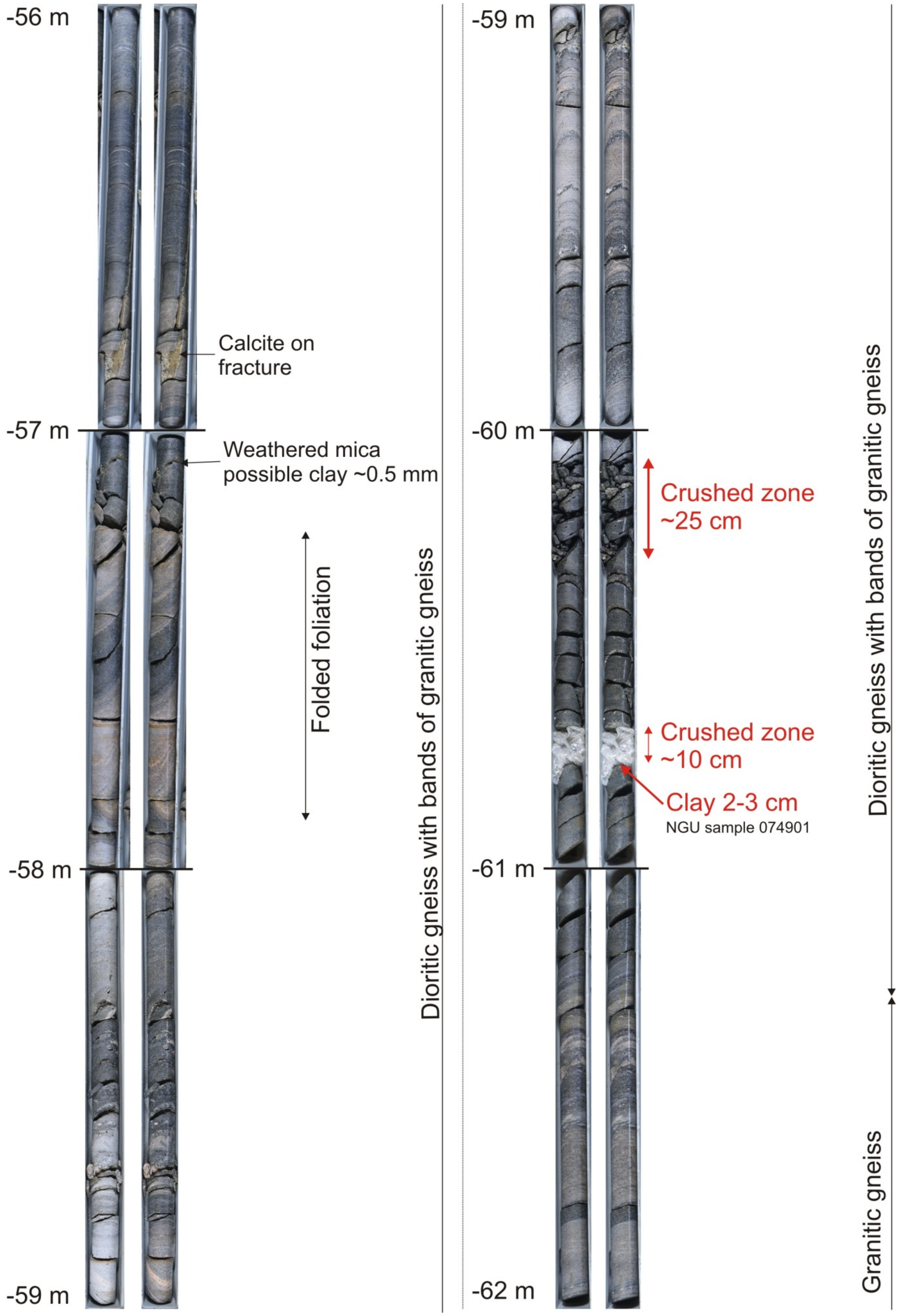

Figure 18. Geological core logging from 56 to 62 m depth with pictures of the dry (left) and wet (right) core.

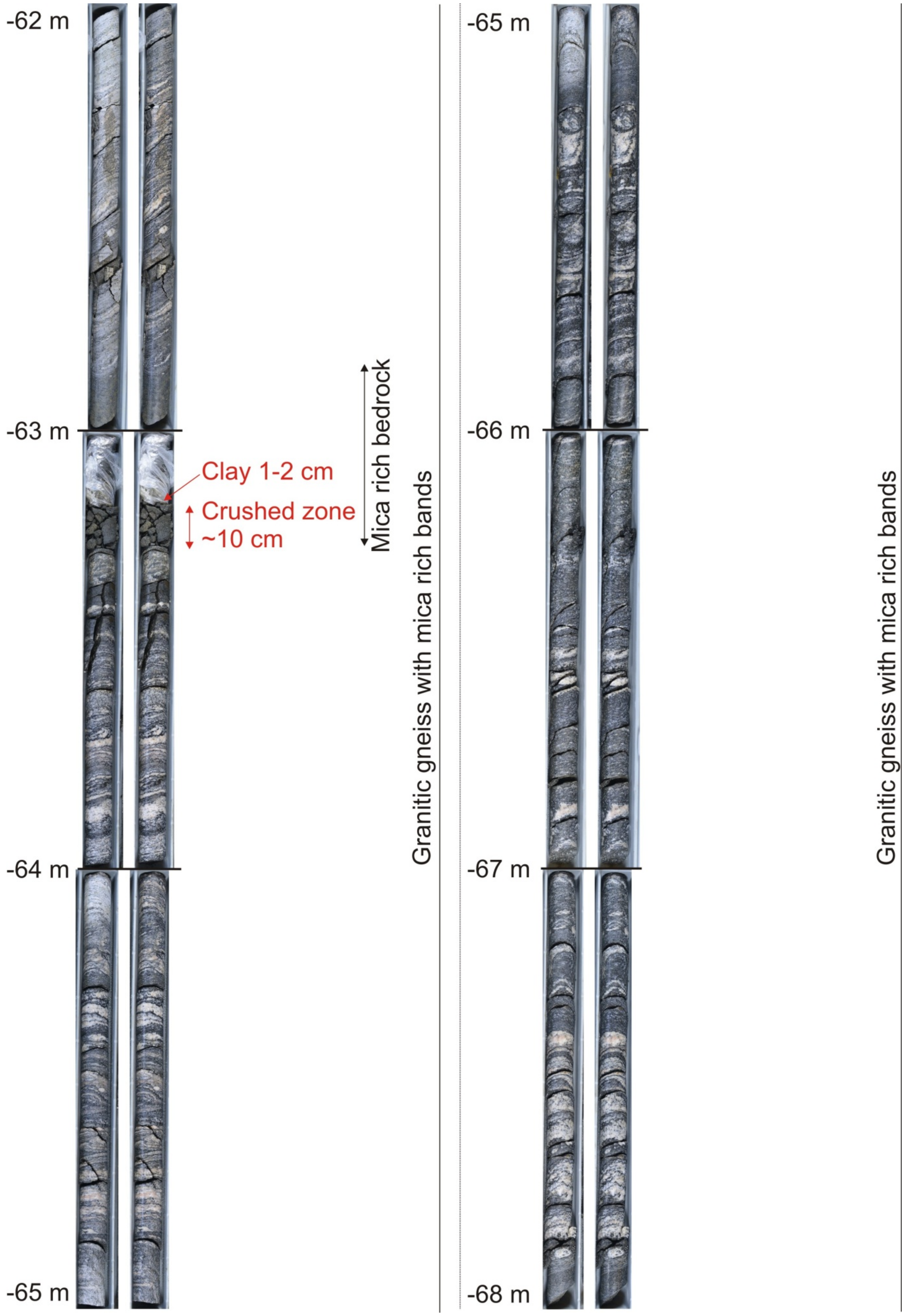

Figure 19. Geological core logging from 62 to 68 m depth with pictures of the dry (left) and wet (right) core.

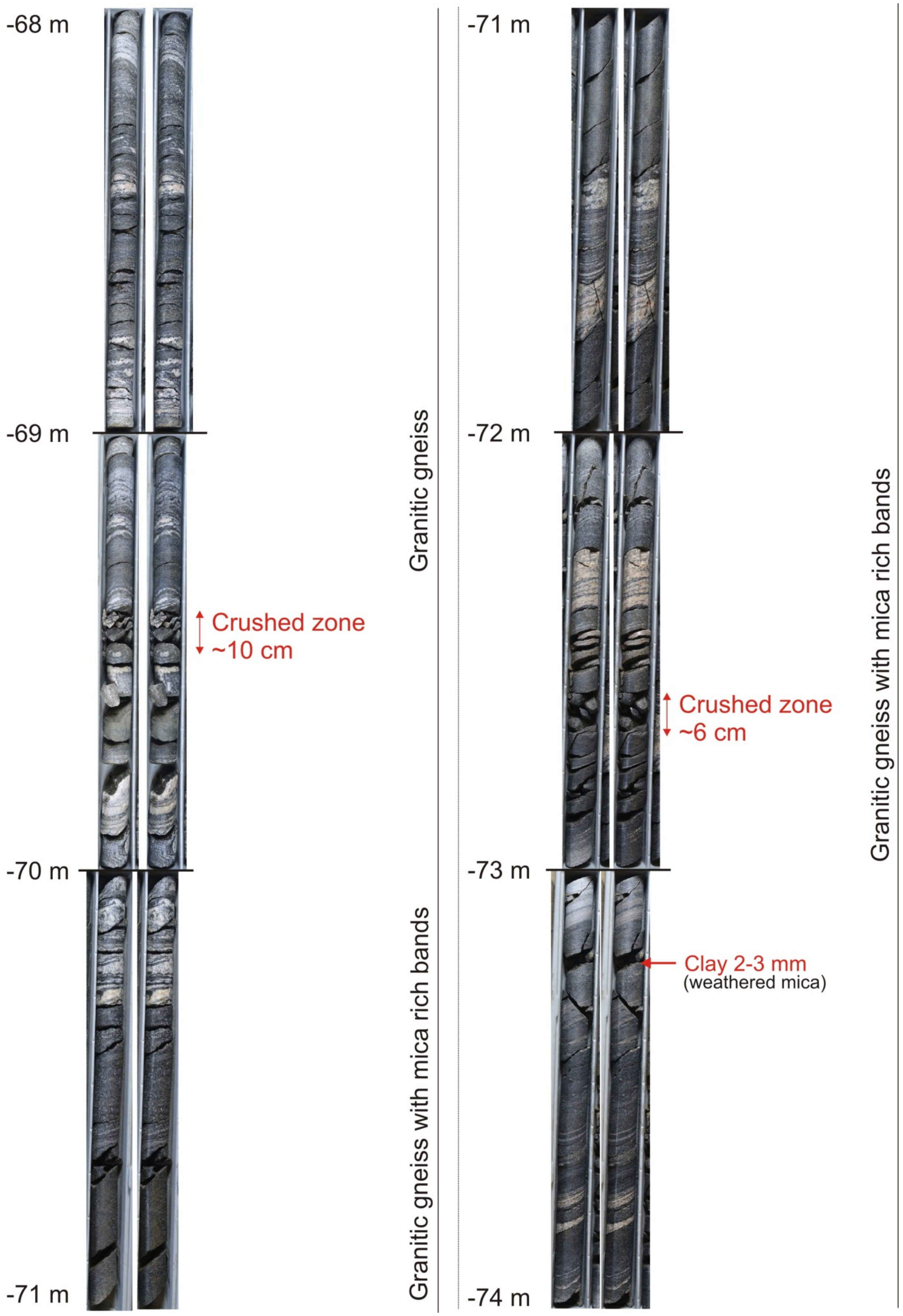

Figure 20. Geological core logging from 68 to 74 m depth with pictures of the dry (left) and wet (right) core.

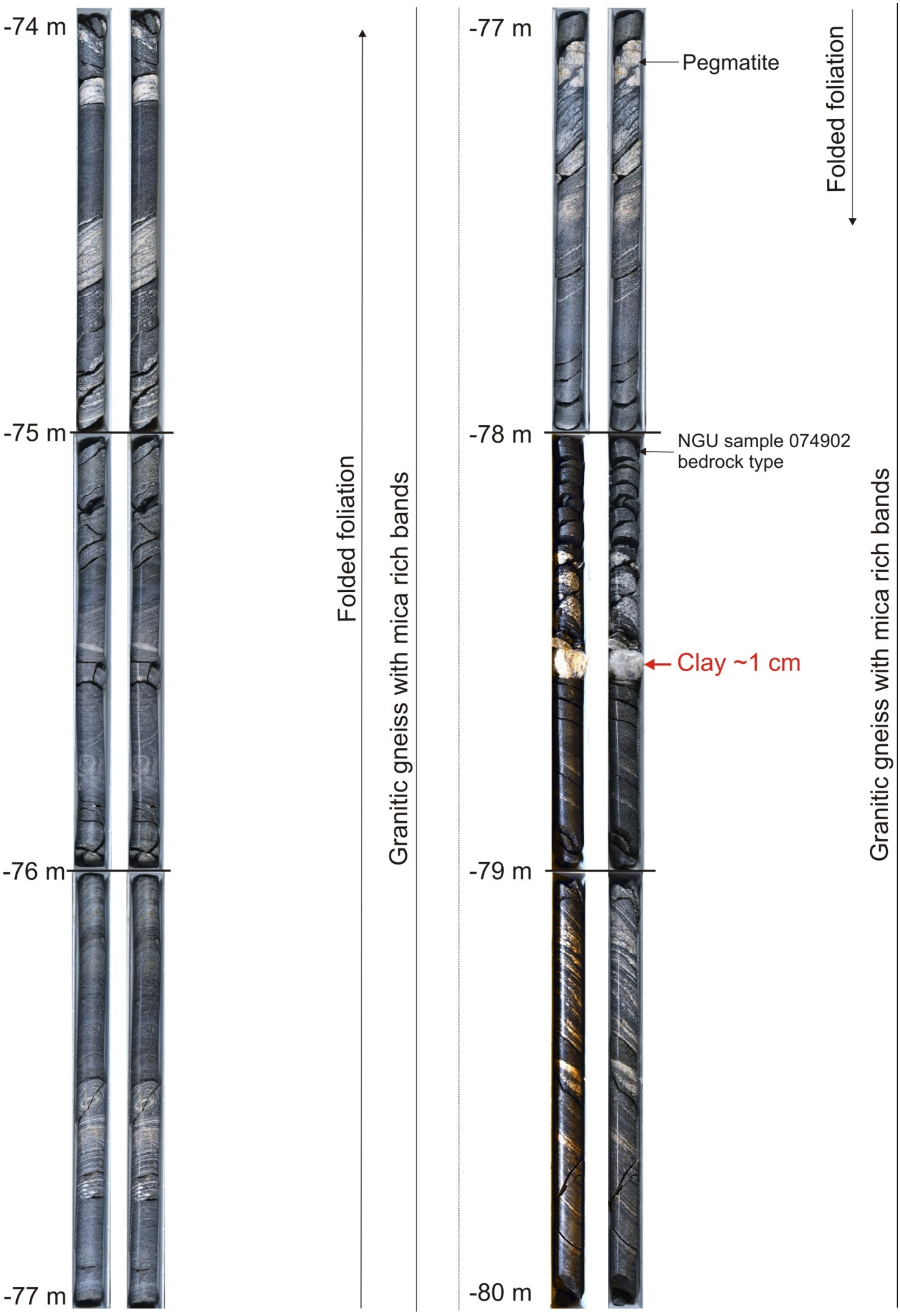

Figure 21. Geological core logging from 74 to 80 m depth with pictures of the dry (left) and wet (right) core.

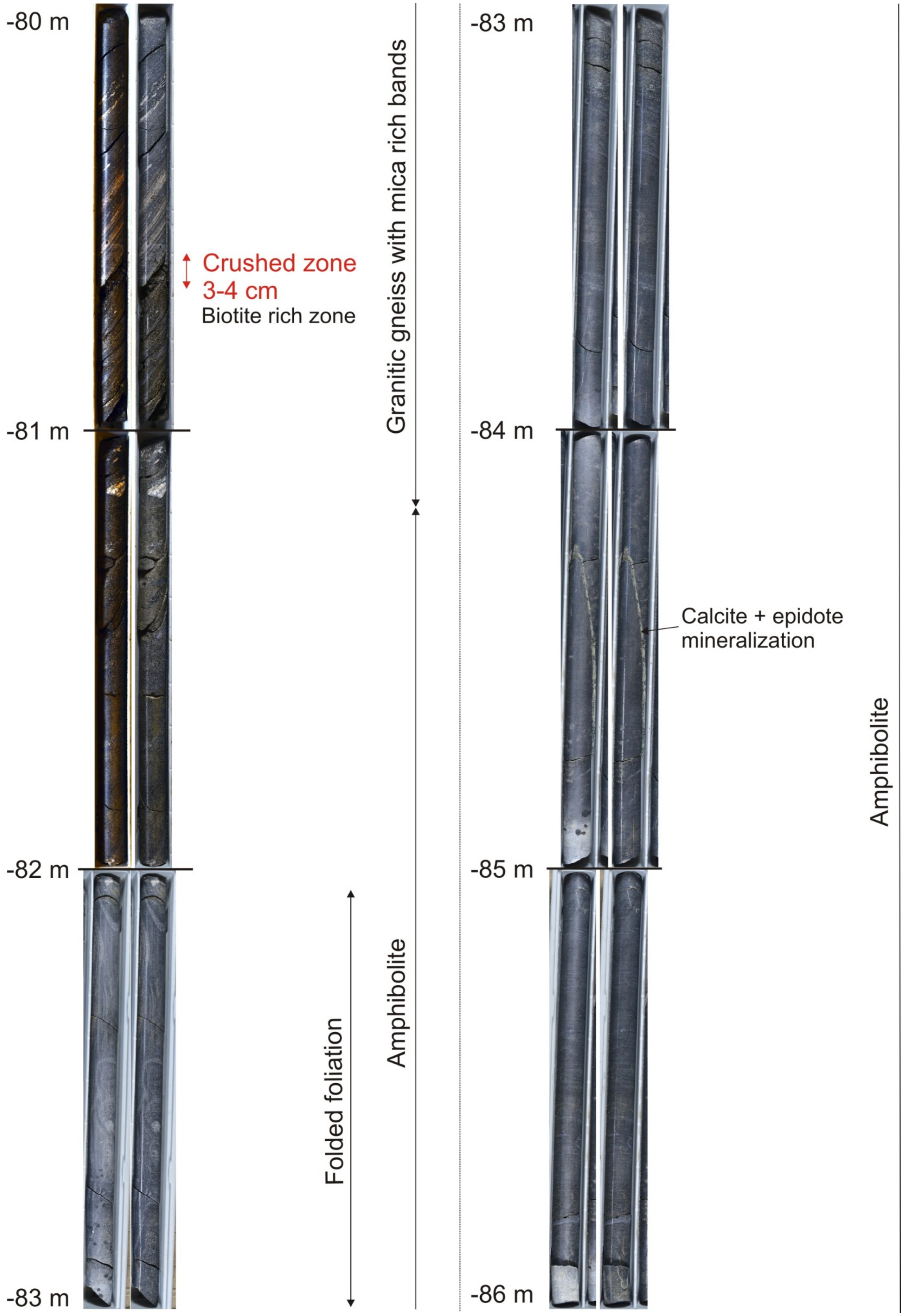

Figure 22. Geological core logging from 80 to 86 m depth with pictures of the dry (left) and wet (right) core.

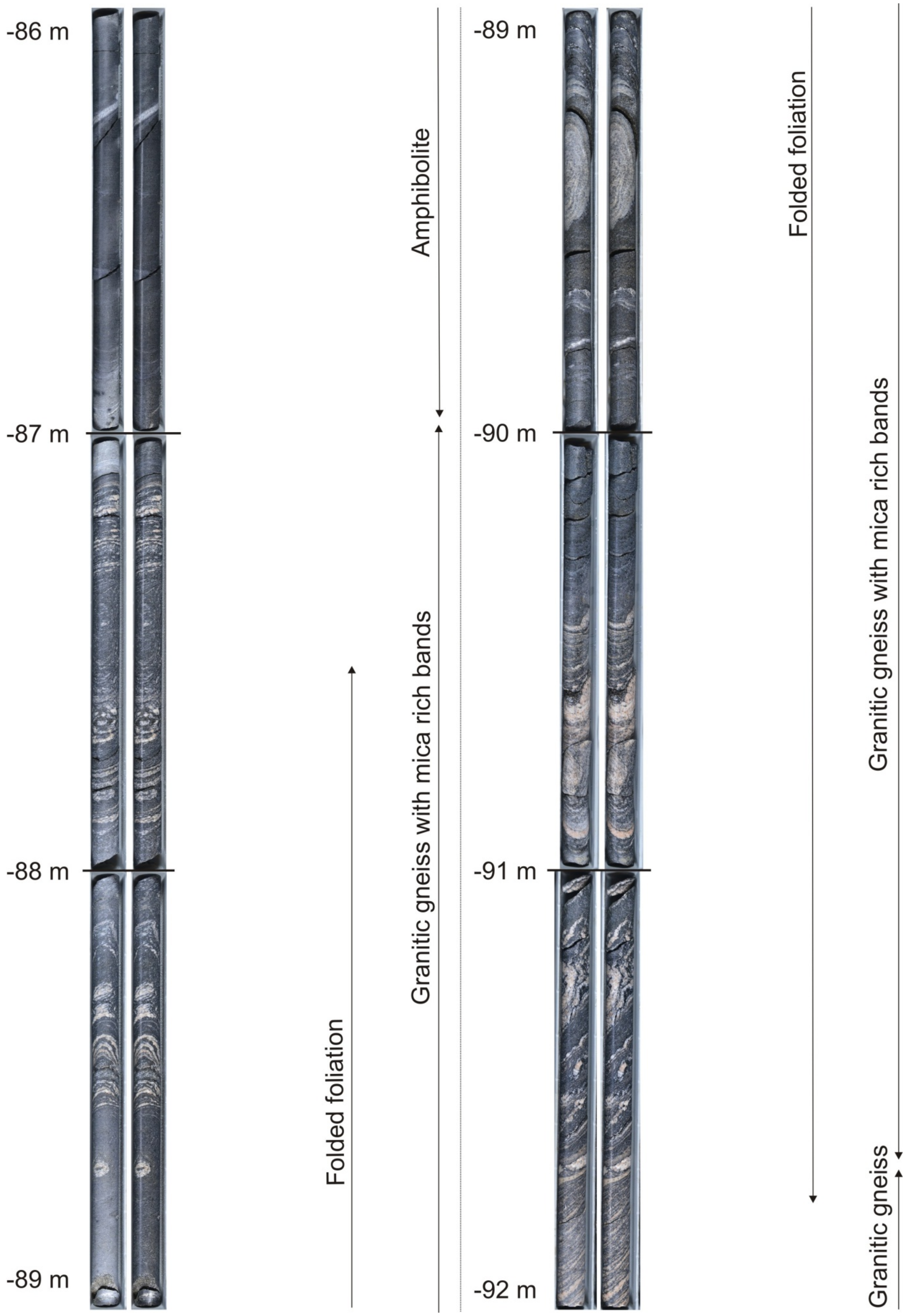

Figure 23. Geological core logging from 86 to 92 m depth with pictures of the dry (left) and wet (right) core.

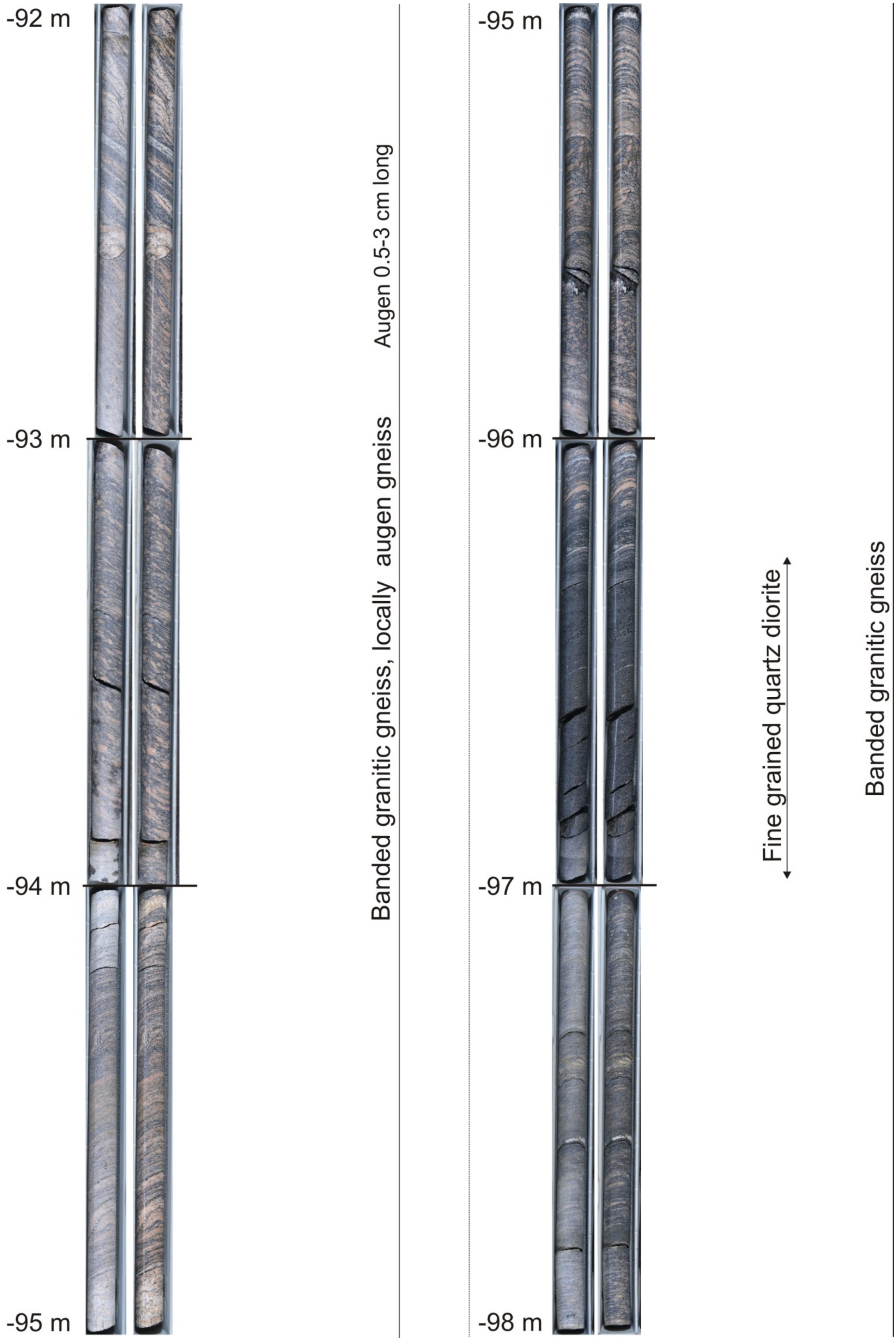

Figure 24. Geological core logging from 92 to 98 m depth with pictures of the dry (left) and wet (right) core.

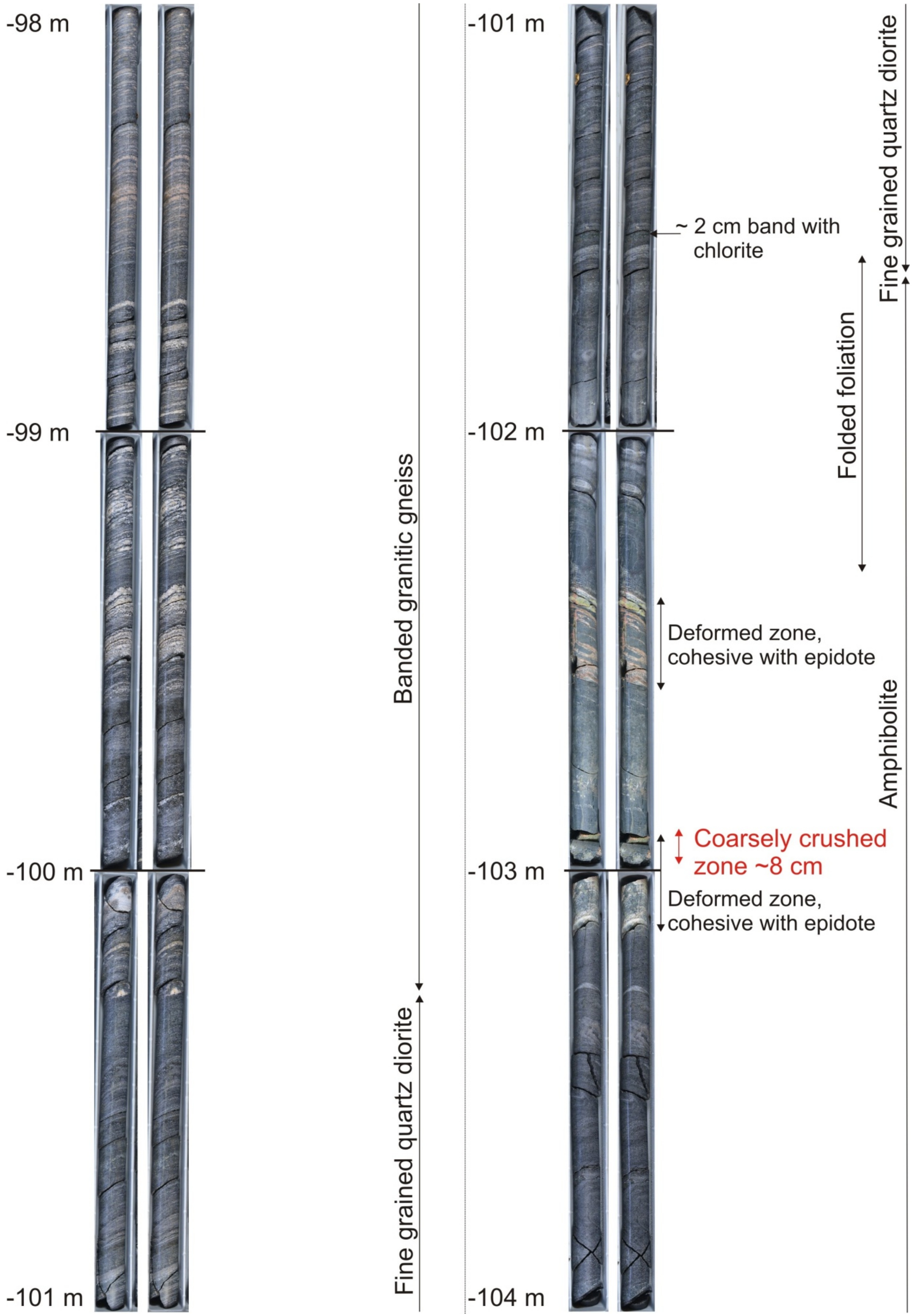

Figure 25. Geological core logging from 98 to 104 m depth with pictures of the dry (left) and wet (right) core.

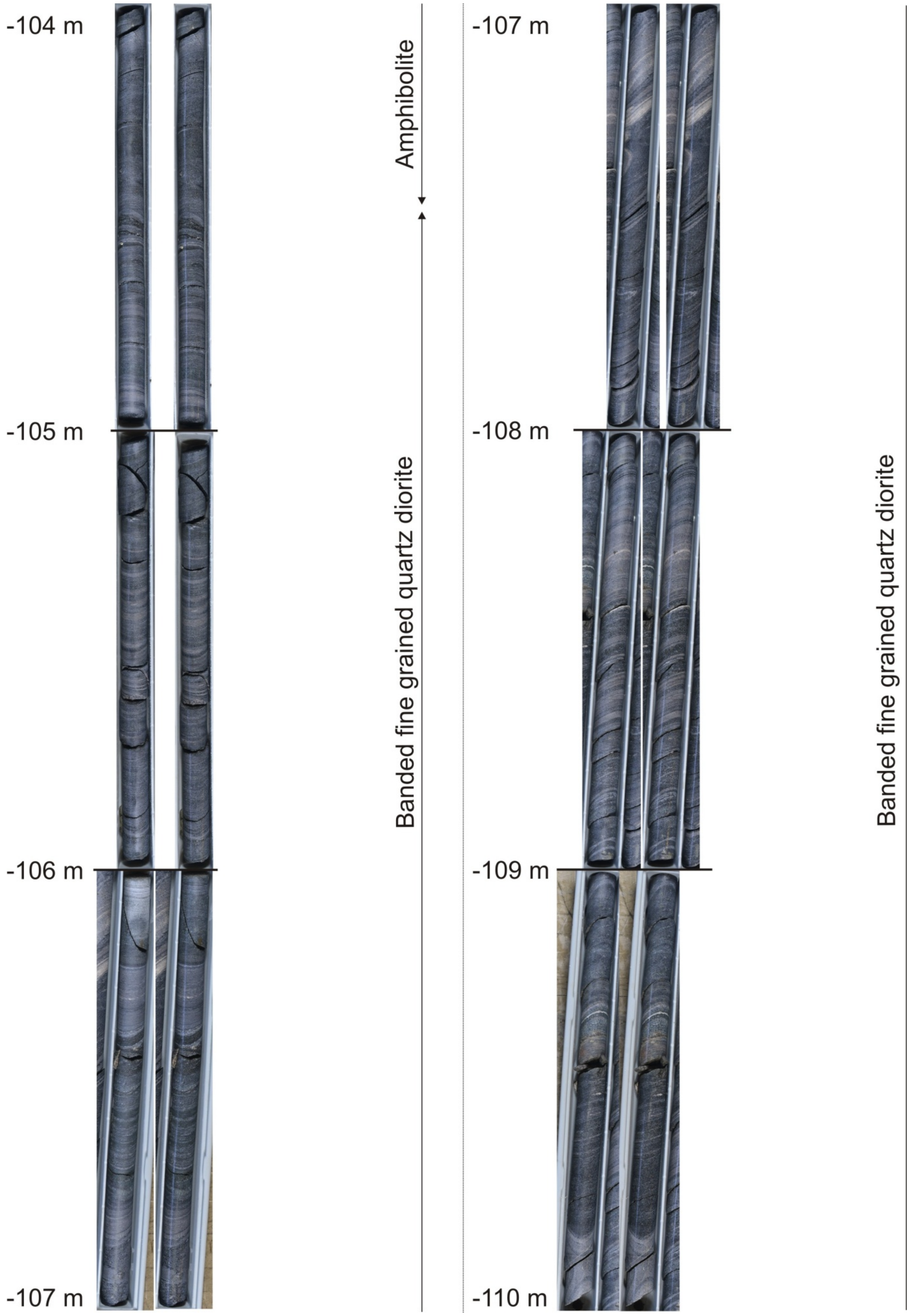

Figure 26. Geological core logging from 104 to 110 m depth with pictures of the dry (left) and wet (right) core.

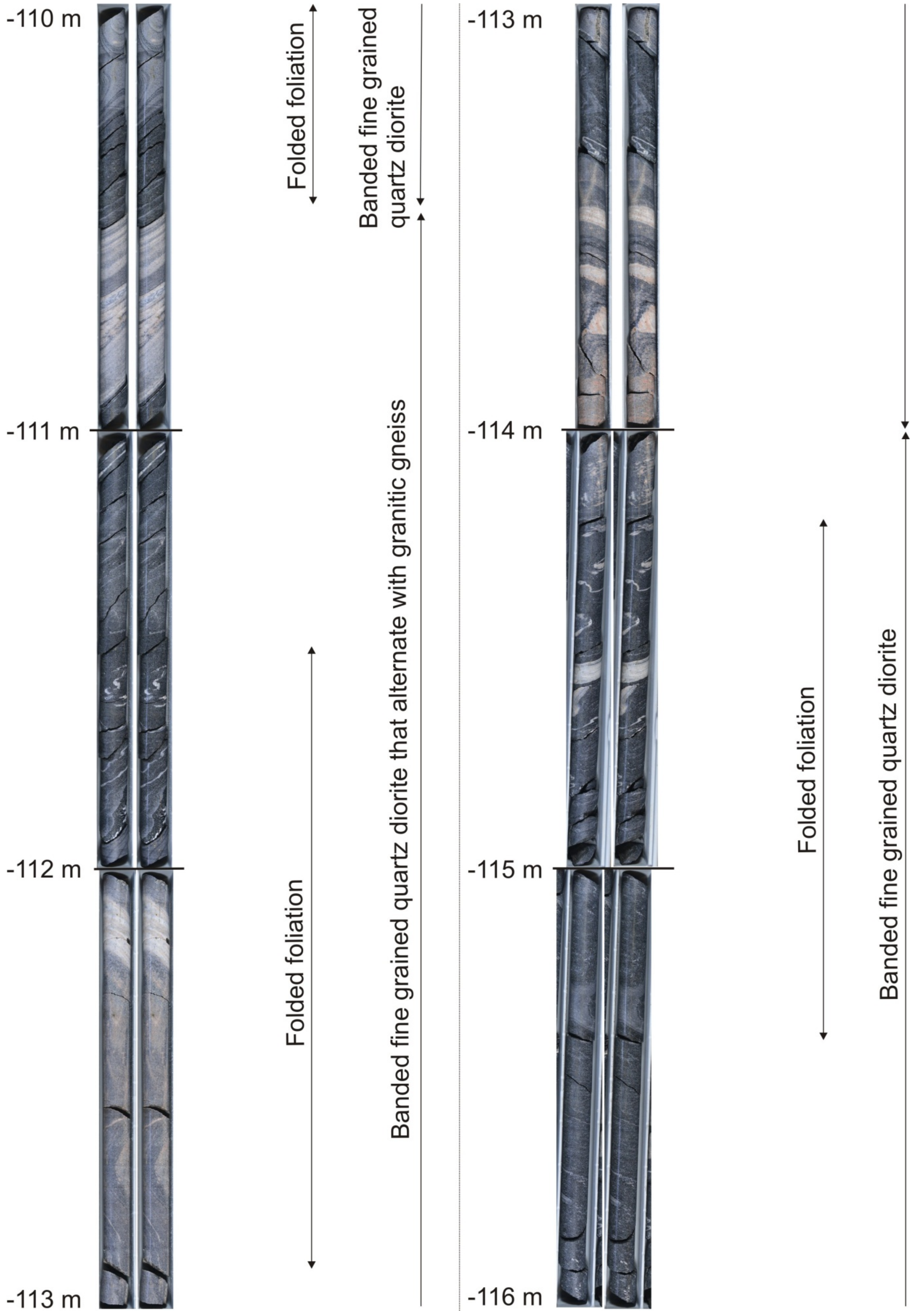

Figure 27. Geological core logging from 110 to 116 m depth with pictures of the dry (left) and wet (right) core.

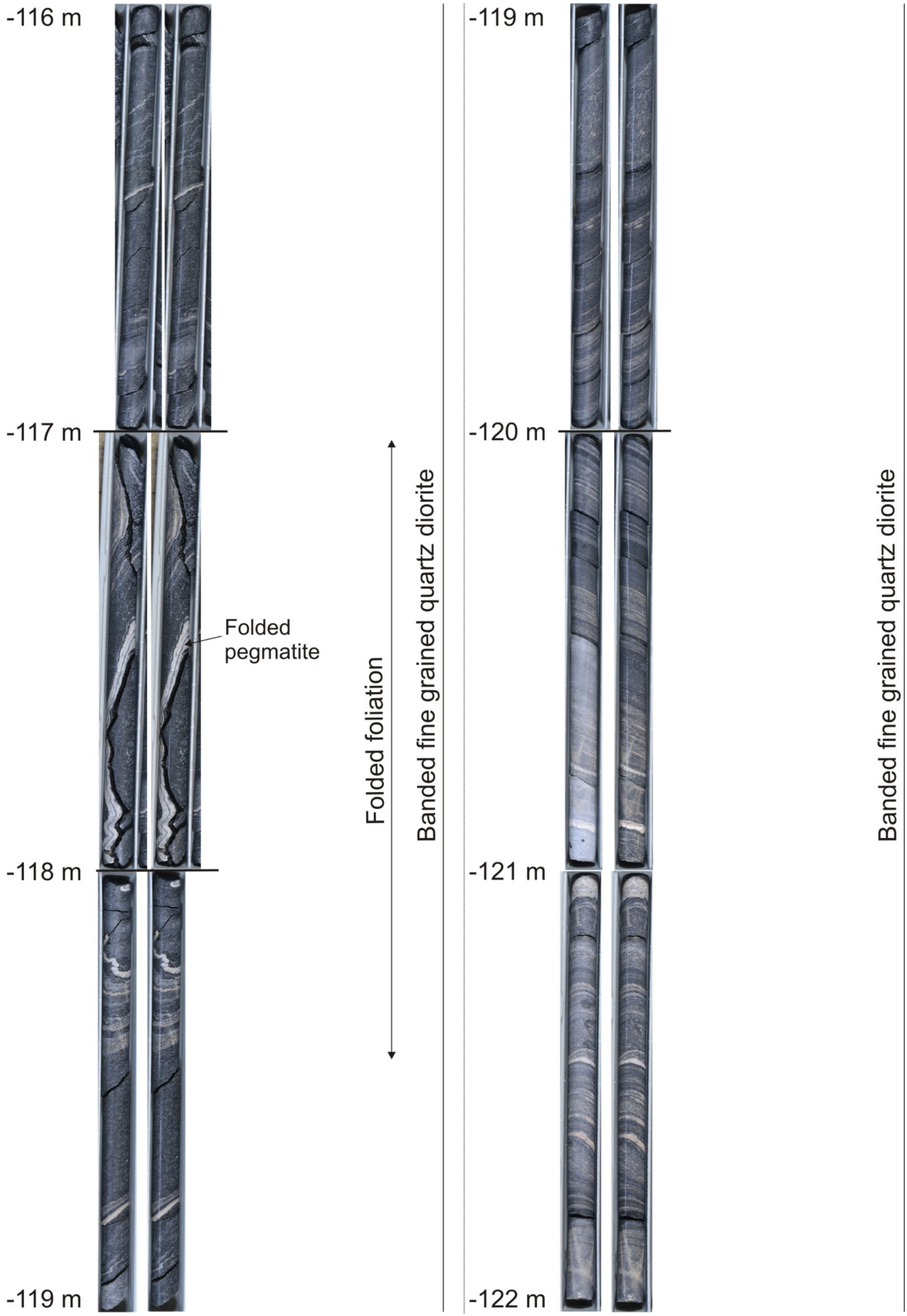

Figure 28. Geological core logging from 116 to 122 m depth with pictures of the dry (left) and wet (right) core.

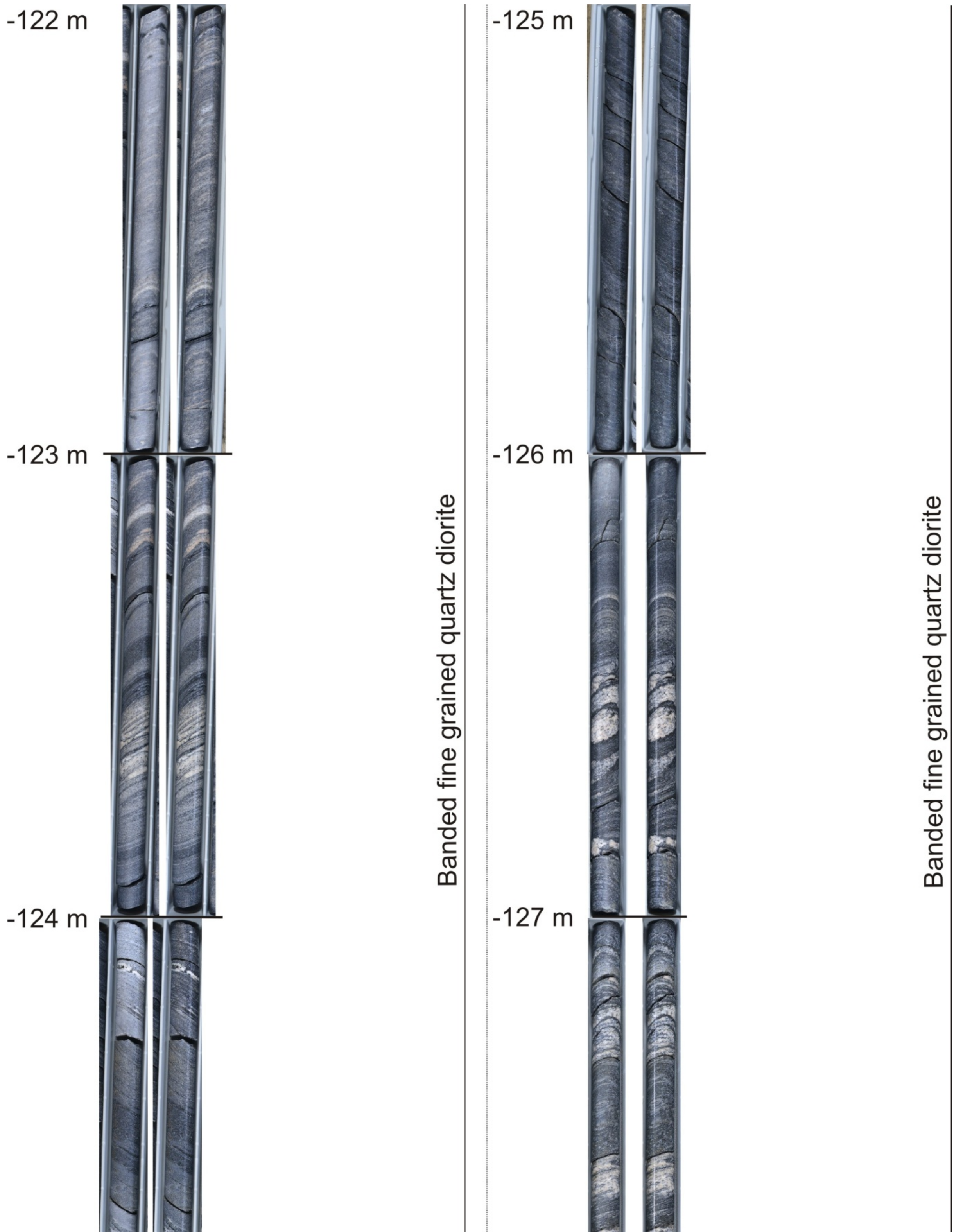

Figure 29. Geological core logging from 122 to 128 m depth with pictures of the dry (left) and wet (right) core.

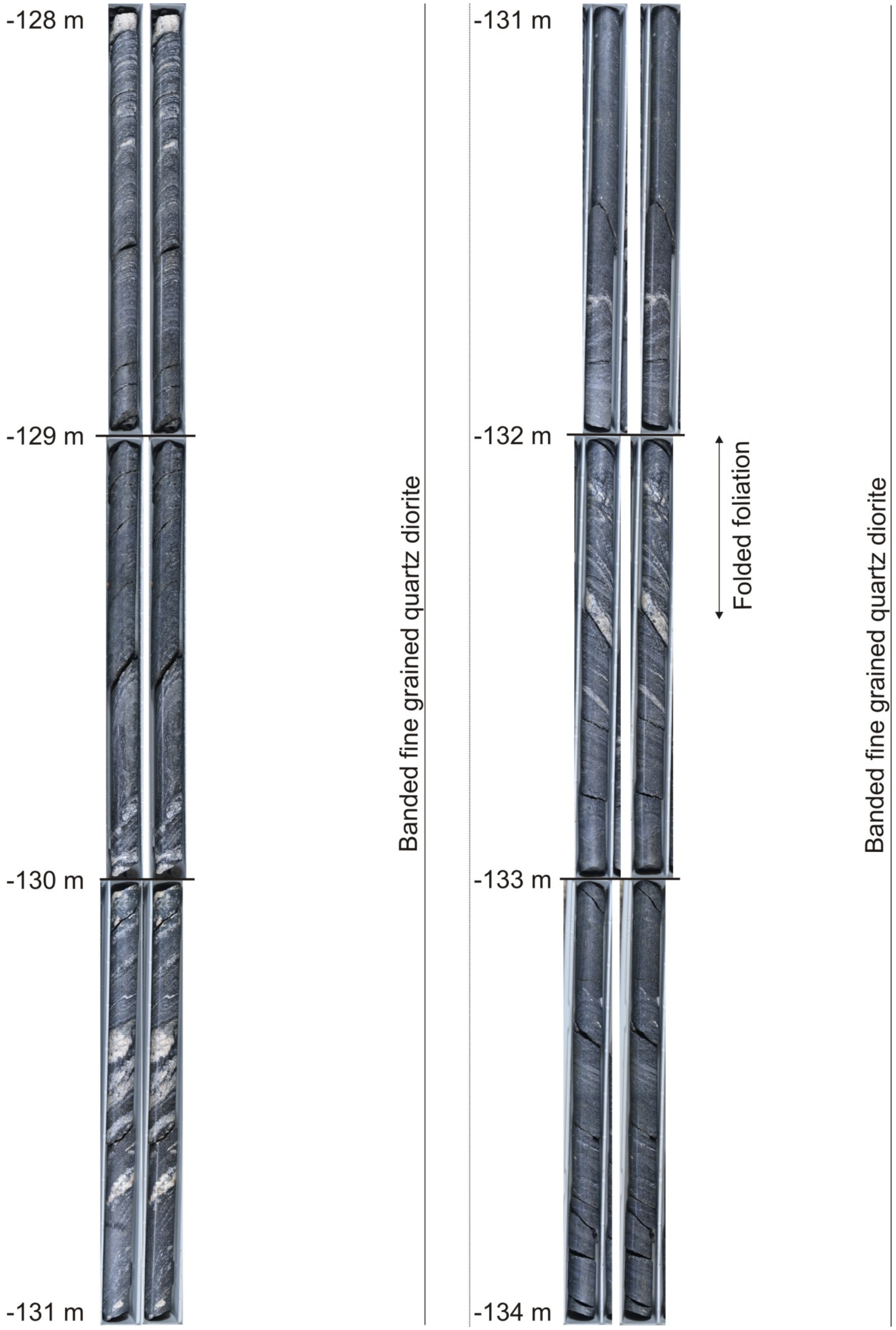

Figure 30. Geological core logging from 128 to 134 m depth with pictures of the dry (left) and wet (right) core.

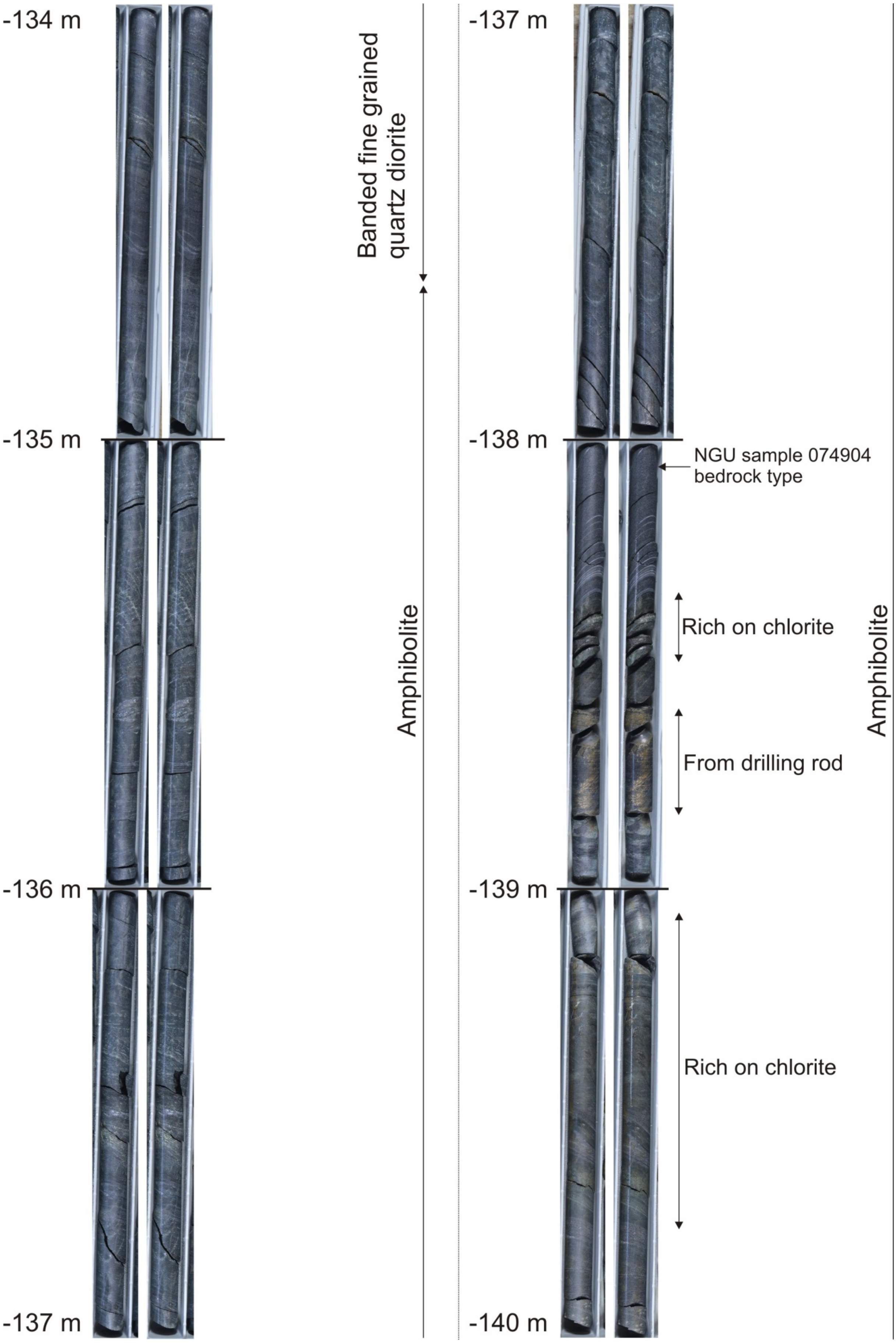

Figure 31. Geological core logging from 134 to 140 m depth with pictures of the dry (left) and wet (right) core.

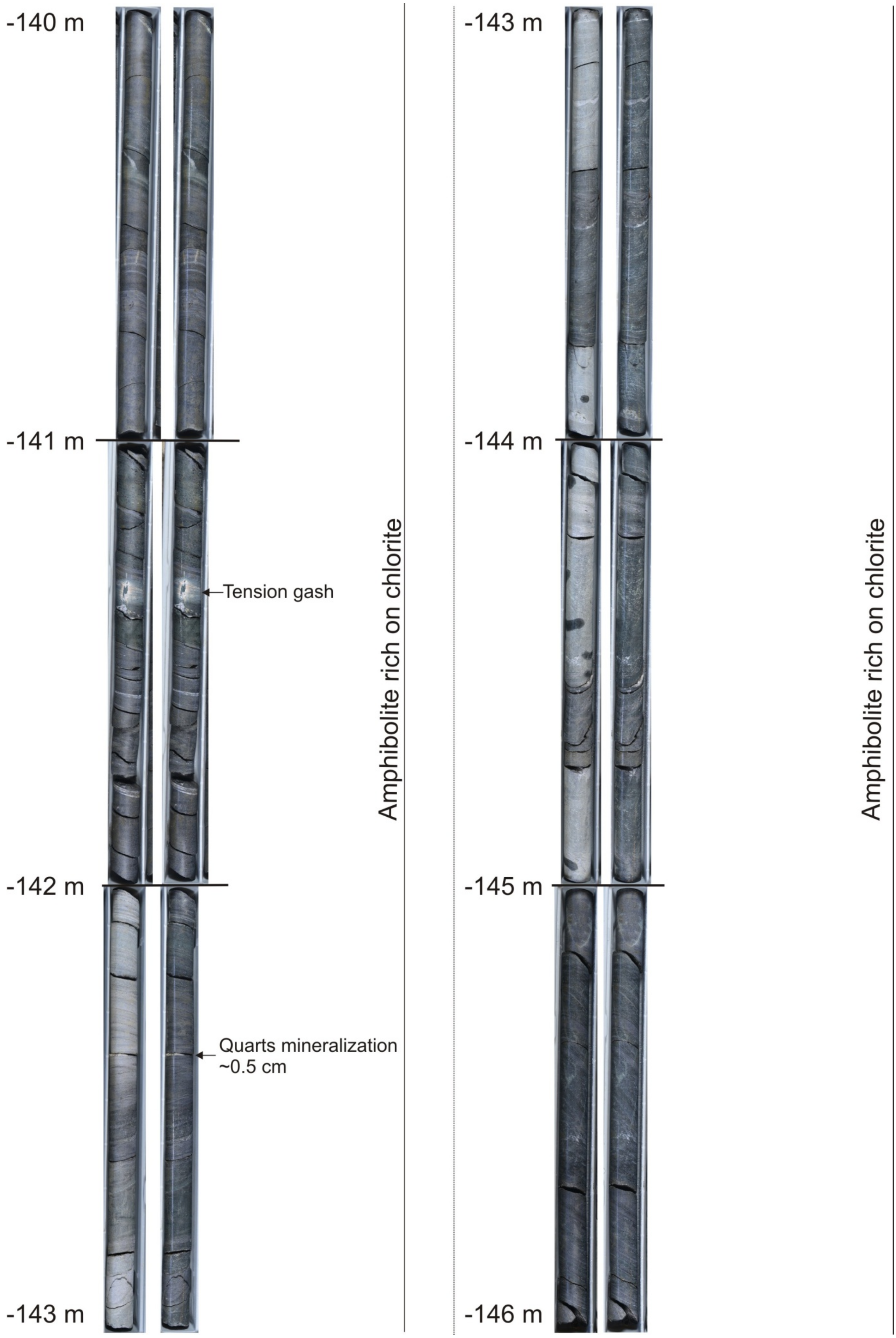

Figure 32. Geological core logging from 140 to 146 m depth with pictures of the dry (left) and wet (right) core.

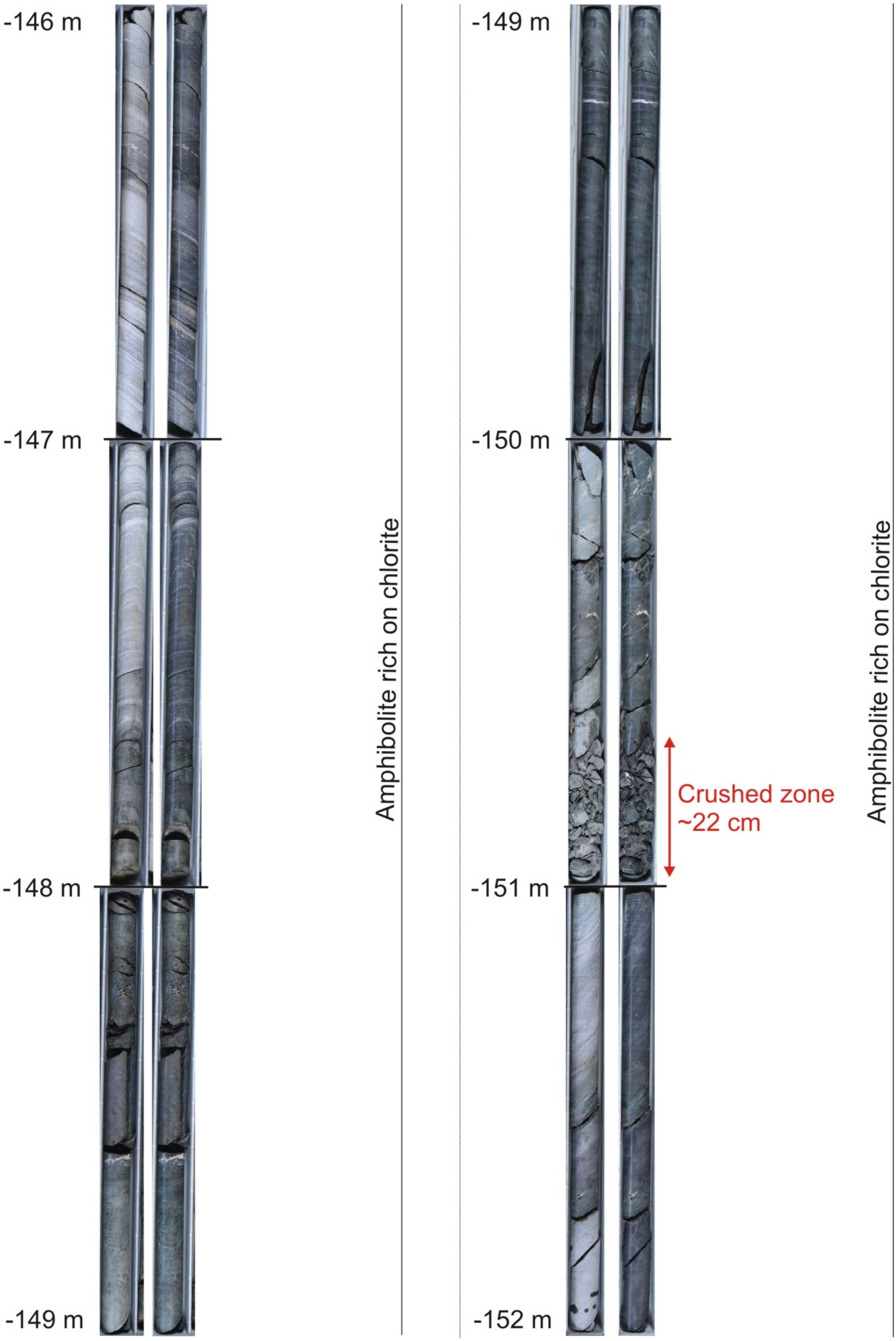

Figure 33. Geological core logging from 146 to 152 m depth with pictures of the dry (left) and wet (right) core.

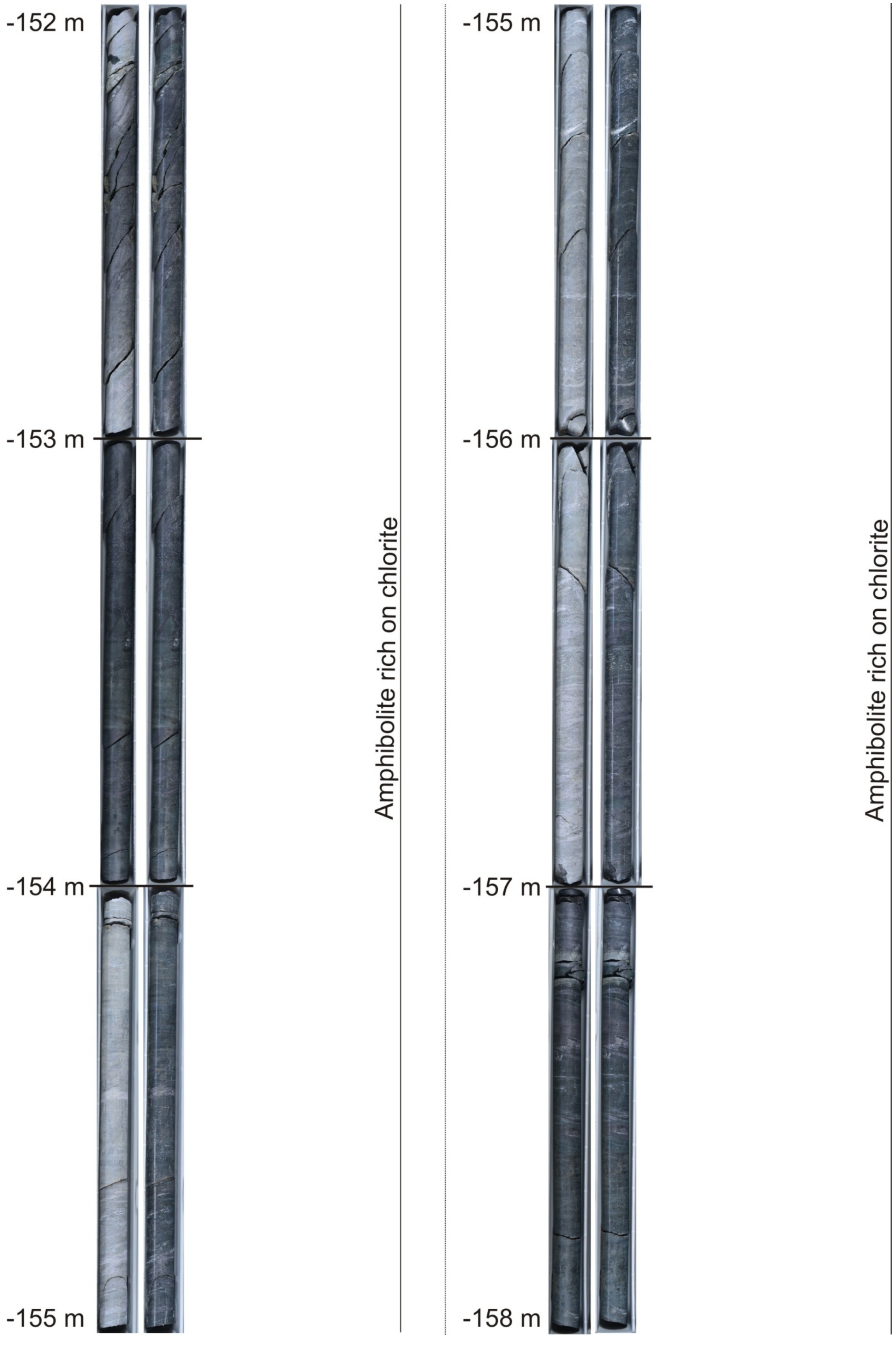

Figure 34. Geological core logging from 152 to 158 m depth with pictures of the dry (left) and wet (right) core.

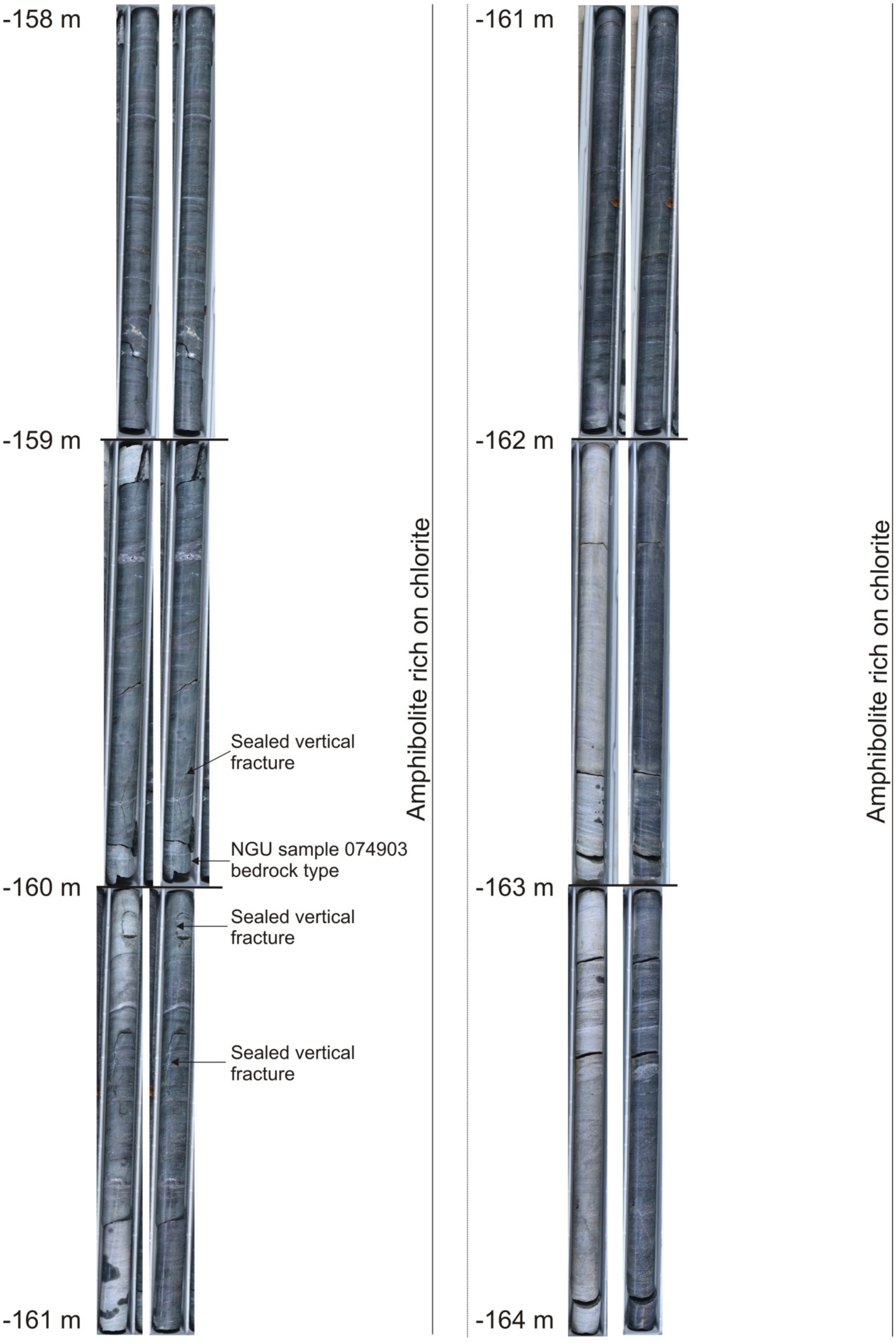

Figure 35. Geological core logging from 158 to 164 m depth with pictures of the dry (left) and wet (right) core.

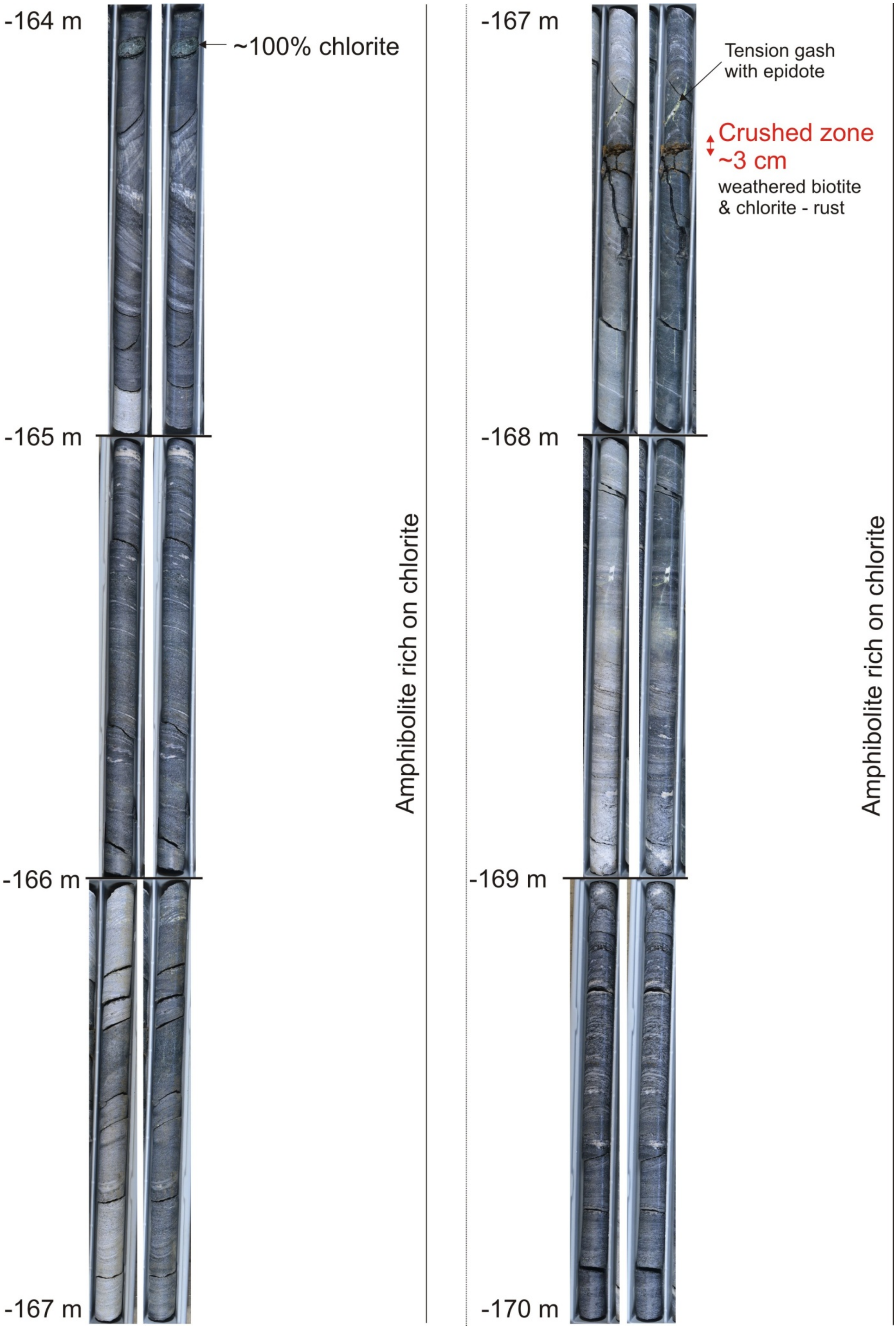

Figure 36. Geological core logging from 164 to 170 m depth with pictures of the dry (left) and wet (right) core.

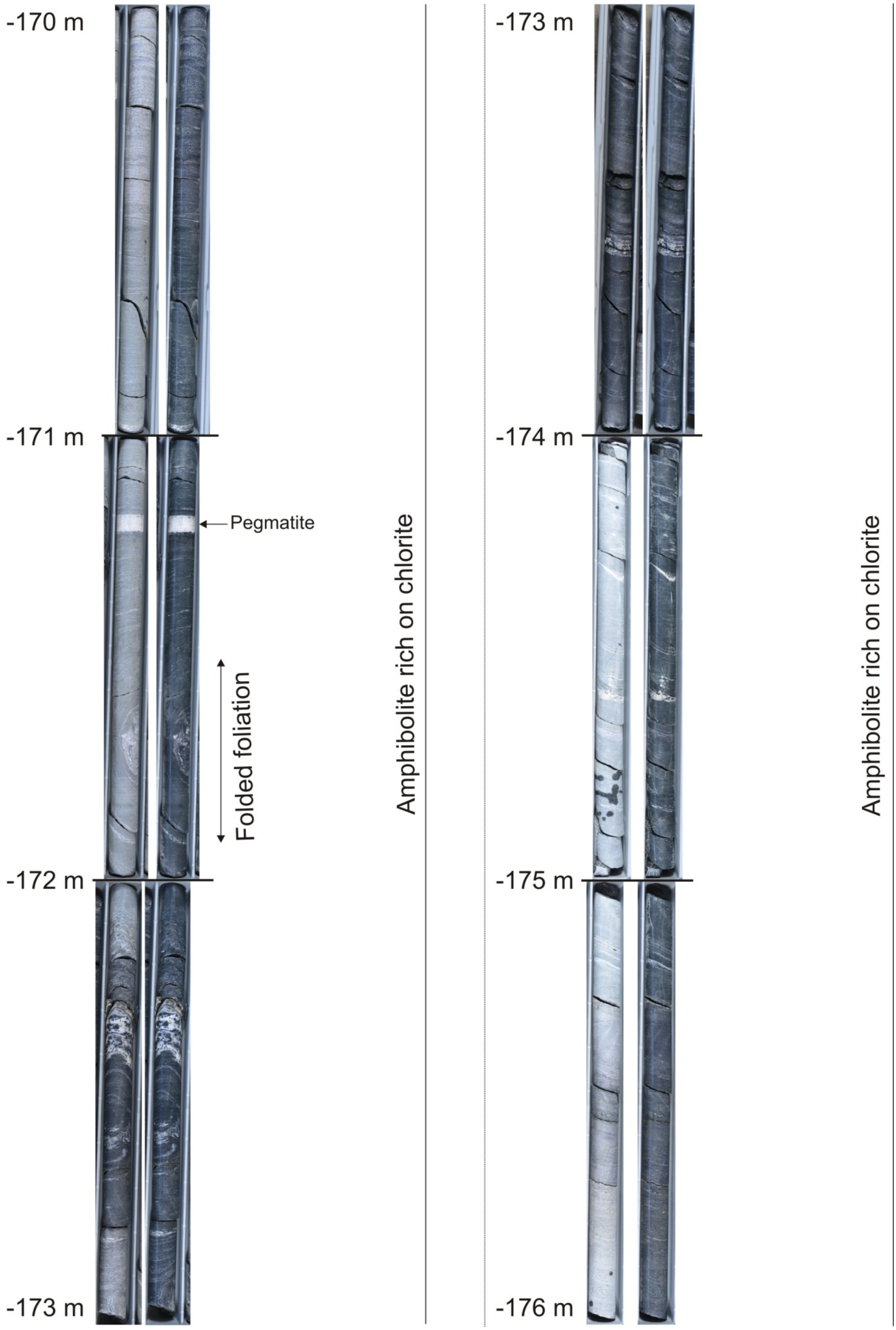

Figure 37. Geological core logging from 170 to 176 m depth with pictures of the dry (left) and wet (right) core.

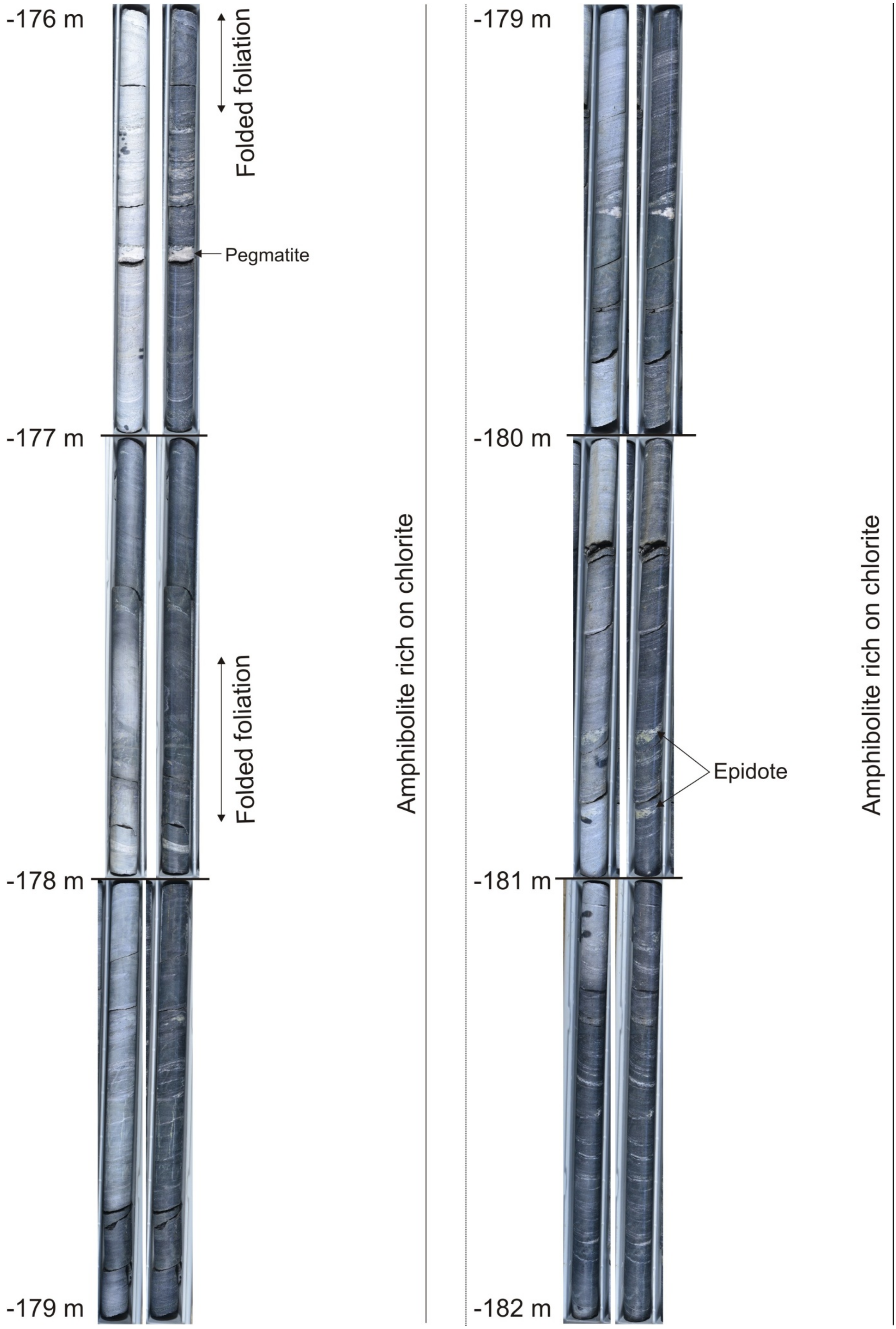

Figure 38. Geological core logging from 176 to 182 m depth with pictures of the dry (left) and wet (right) core.

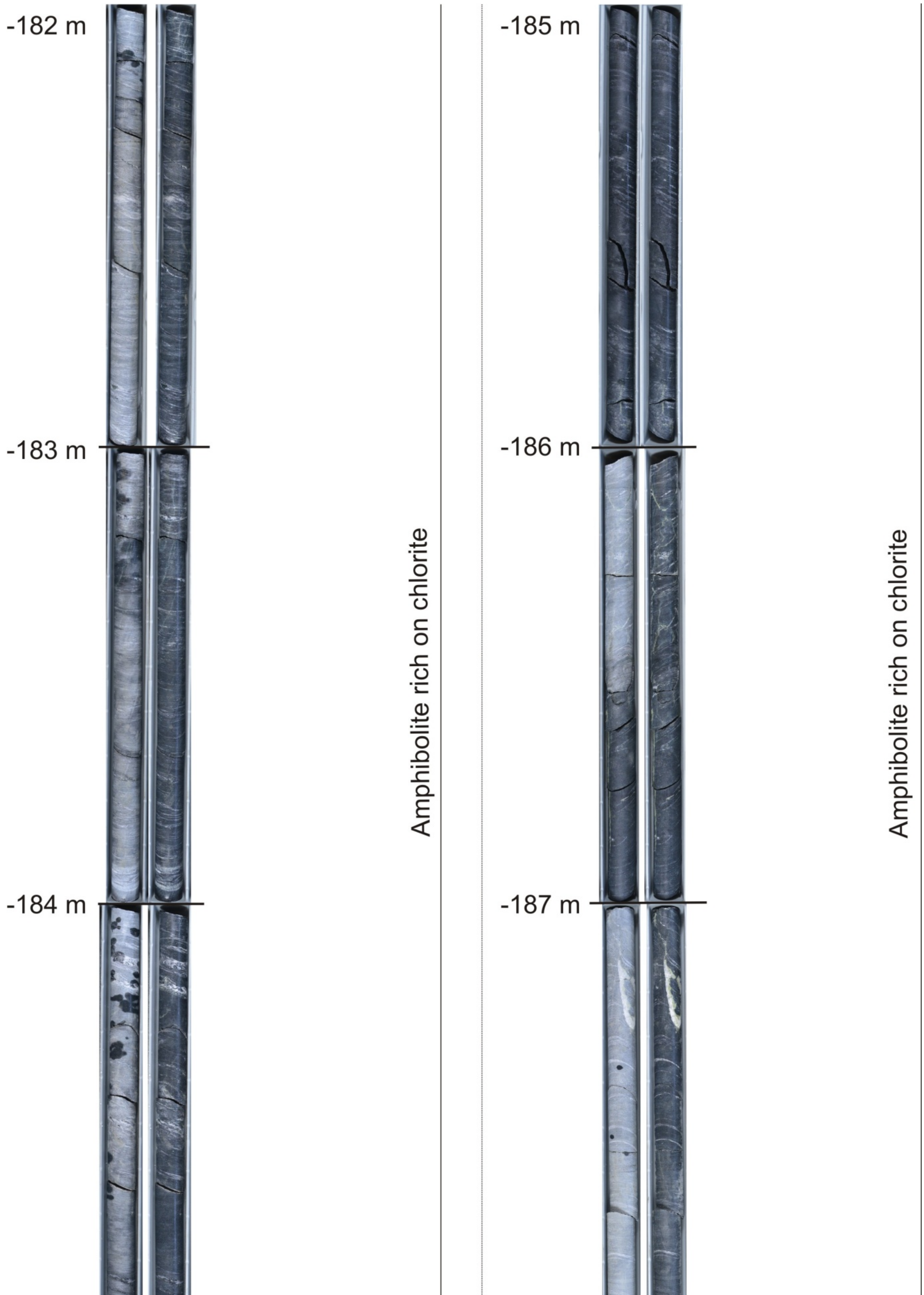

Figure 39. Geological core logging from 182 to 188 m depth with pictures of the dry (left) and wet (right) core.

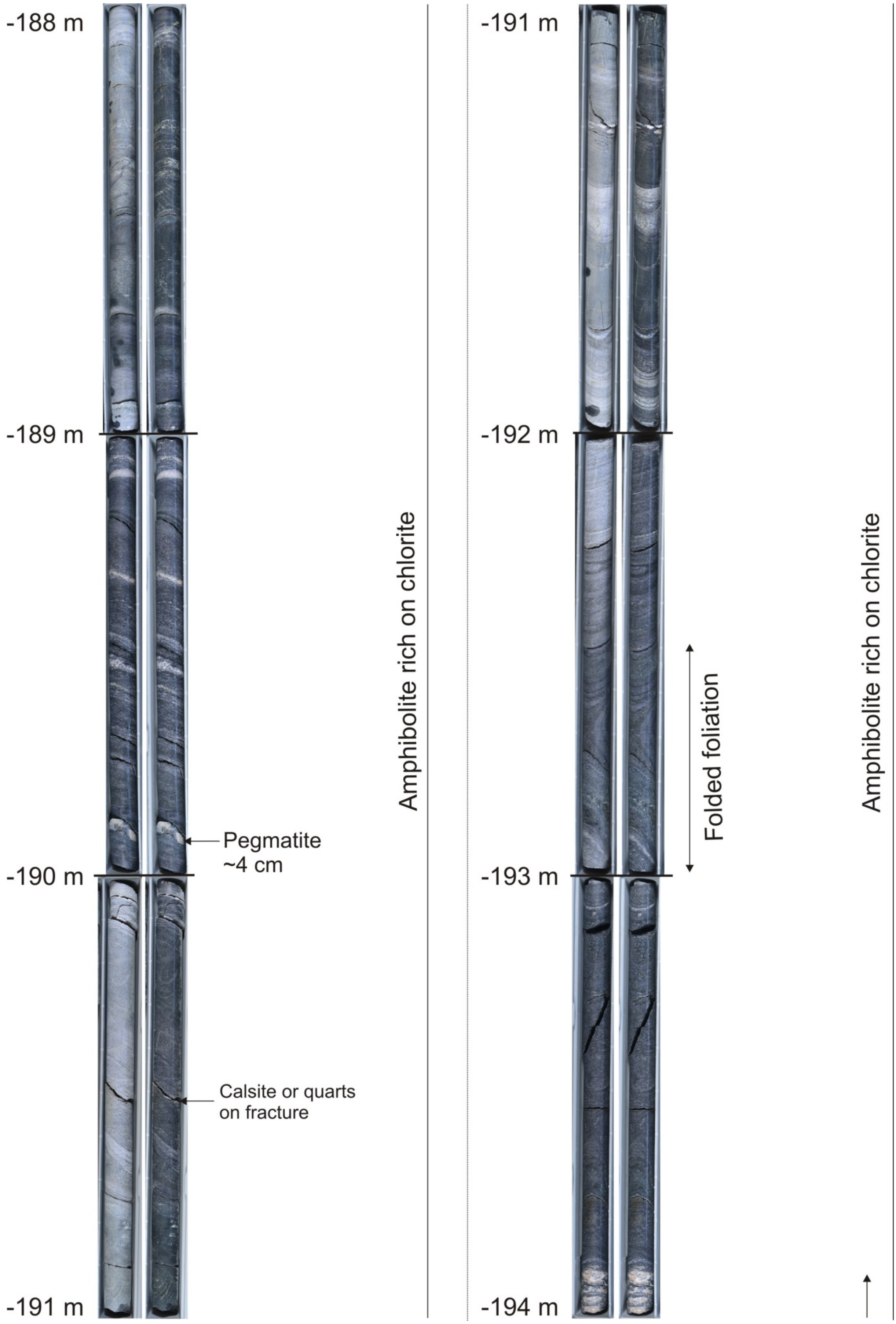

Figure 40. Geological core logging from 188 to 194 m depth with pictures of the dry (left) and wet (right) core.

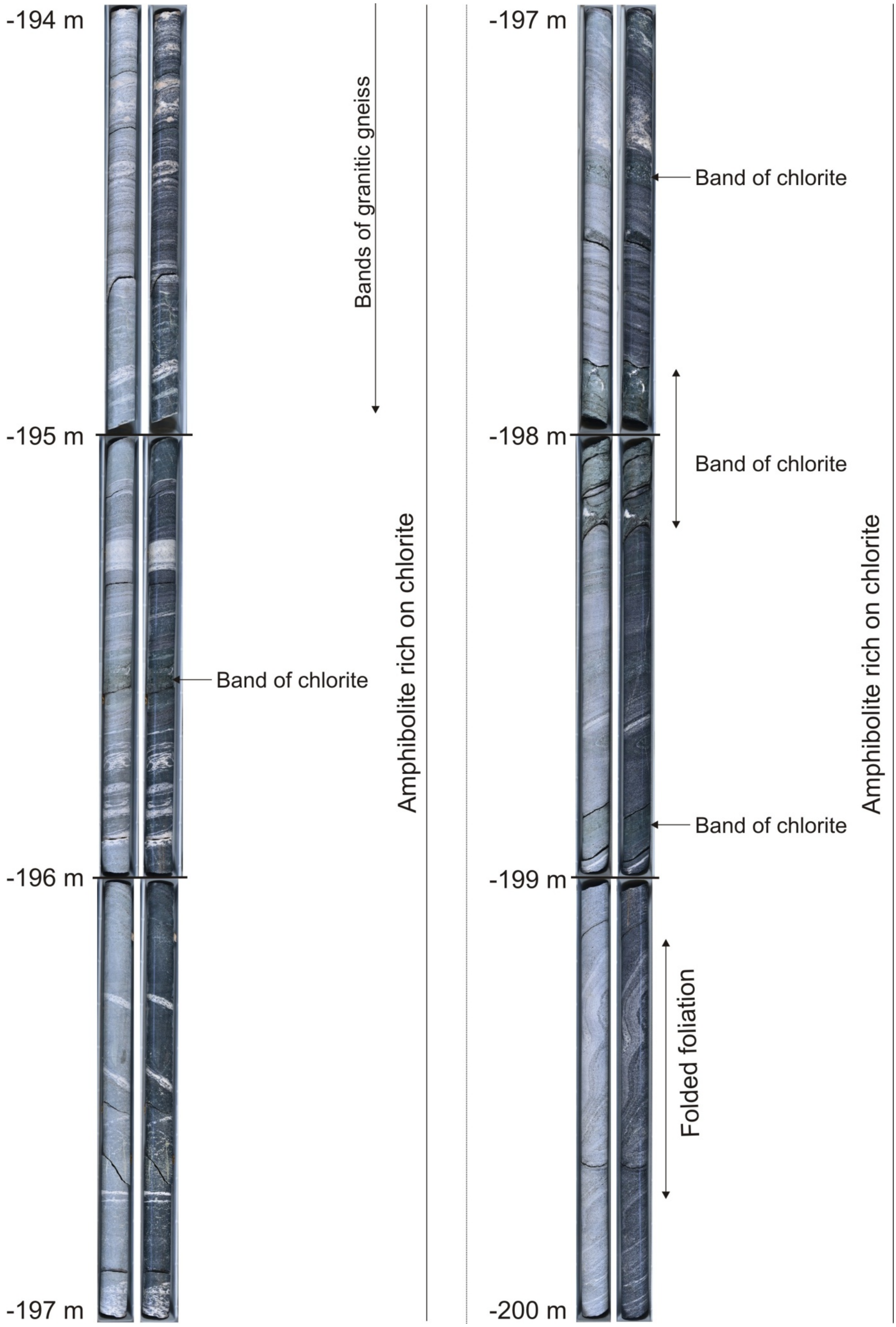

Figure 41. Geological core logging from 194 to 200 m depth with pictures of the dry (left) and wet (right) core.

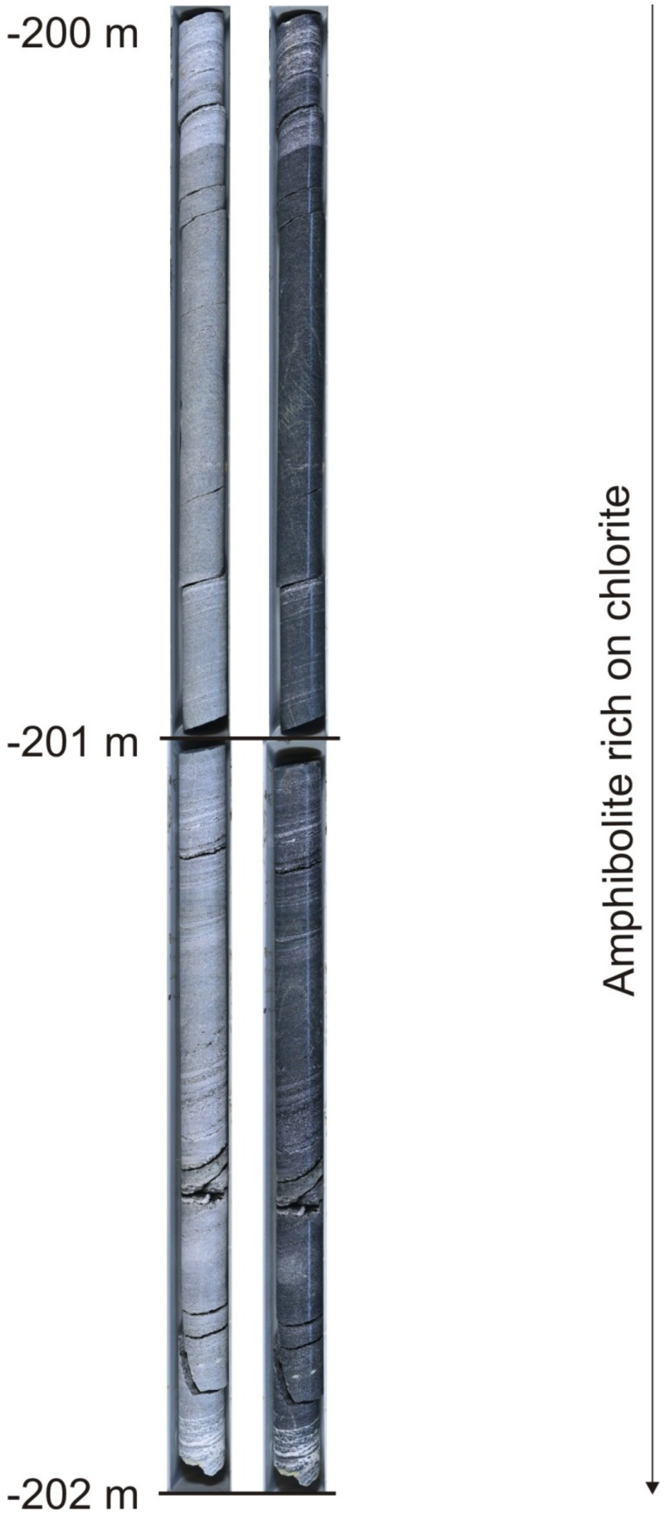

Figure 42. Geological core logging from 200 to ca. 202 m depth with pictures of the dry (left) and wet (right) core.

3. CONCLUSION

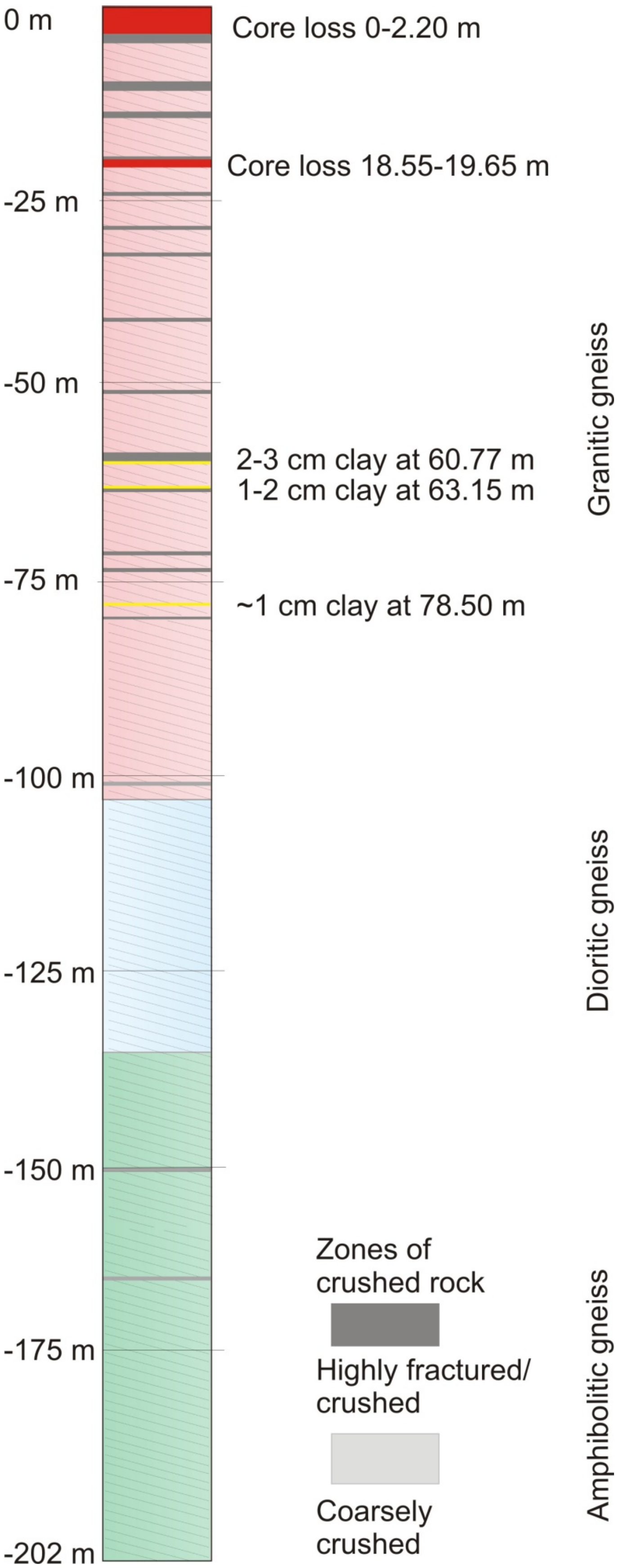

Figure 43. An overview of the log from drill core KH-08-12.

An overview of the drill core logging is given in Figure 43, highlighting clay zones, zones of crushed rock and bedrock types. Thin clay zones are observed at 60.77 m, 63.15 m and 78.50 m where the zone at 60.77 m has the most well developed clay containing mainly fine grained particles (Figure 3). The two first clay zones are combined with zones of crushed rock, and are regarded as the part absorbing the most movement. The upper 0-80 meters has the highest fracturing (Figure 7 and Figure 8), while the lower 80-202 meter has close to background fracturing (2-3 fracture/meter). Fractures that are obviously made by the drilling process are recorded and they are especially clear in the lower part of the drill core (Figure 7 and Figure 8). A crushed zone of 22 cm is observed at ca. 150.75-151 meter (Figure 33). This zone of crushed rock is located in an otherwise competent bedrock, amphibolitic gneiss, that has good rock quality.

Three different bedrock types are observed with granitic gneiss in the upper 0-100 meter, dioritic gneiss at 100-134 meter and amphibolitic gneiss at 134 meter and downwards. The bedrock has a pervasive foliation with general sub-horizontal orientation that locally is folded.

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