Progress Report (WP 4.2.3) – Field Installation and Rock Characterisation

FORGE Report D4.9 – VER.1

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Euratom 7th Framework Programme Project: FORGE

EURATOM

Fate of repository gases (FORGE)

The multiple barrier concept forms the cornerstone of all the schemes envisaged for the underground disposal of radioactive waste. The concept proposes a series of barriers, both engineered and natural, to be positioned between the waste and the surface. The realisation of this concept is the primary objective of all the various disposal programmes put forward to date and will involve a process beginning with site appraisal and characterisation followed by the design of the repository itself and ending with construction and commissioning. However, the eventual performance of the repository as a whole (waste, barriers, engineering disturbed zone, host rock) and, in particular, gas transport have still not been thoroughly examined. Issues relating to a full understanding of basic processes and which still need to be fully investigated include: dilational versus visco-capillary flow mechanisms; the long-term integrity of the seals, in particular gas flow along contact zones; the role of the EDZ as a conduit for preferential flow and laboratory to field up-scaling. Understanding gas generation and migration is thus vital when considering the quantitative assessment of repositories and forms the focus for research in the integrated, multi-disciplinary project described herein. The FORGE project is a pan-European project with links to international radioactive waste management organisations, regulators and academia, specifically designed to tackle the key research issues associated with the generation and movement of repository gases. The long-term performance of bentonite buffers, plastic clays, indurated mudrocks and crystalline formations are of particular importance. Further experimental data is required to reduce the uncertainty relating to the quantitative treatment of gases in performance assessment. FORGE will address these issues through a series of laboratory and field-scale experiments, including the development of new up-scaling methods which will allow the optimisation of concepts through detailed scenario analysis. FORGE partners are committed to training and CPD through the provision of a broad portfolio of training opportunities and initiatives which form a significant part of the project.

Further details on the FORGE project and its results can be accessed at www.FORGEproject.org.

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Summary

This report forms a contribution to Work Package 4 (WP 4.2.3, Deliverable 4.9 - field installation and rock characterisation).

The report provides a description of the rock characterisation of the Josef UEF (Underground Educational Facility) and preparatory work for the study of gas transport through disturbed crystalline rock, presents the results of an extensive geological survey and borehole drilling and provides an outline of the preparation of equipment to be used for gas injection testing purposes.

Introduction

This progress report describes the geological conditions at the Josef UEF (Underground Educational Facility) and provides rock characterisations for those locations selected for the in-situ testing of gas transport in disturbed crystalline rock. Boreholes were drilled in selected locations at the Josef UEF to be used for the measurement of permeability within the rock mass. The sites selected were mapped in detail using a number of rock mass classification systems.

The first part of the report describes the history and geology of the Josef UEF. The second part goes on to describe in detail the rock characterisation of selected testing locations at the facility and provides a summary of the results of the geological survey and the classification of the rock mass.

The third section provides a description of the preparation and installation of the in-situ experimental equipment to be used for the taking of gas injection measurements; a unique set of apparatus has been acquired by the CEG for the measurement of gas permeability.

Josef Underground Educational Facility

The Josef Underground Educational Facility (Josef UEF), opened by the Faculty of Civil Engineering (Czech Technical University (CTU), Prague) in June 2007, is being used for the in-situ study of gas transport through disturbed crystalline rock. The facility is located near the Slapy dam close to the villages of Čelina and Mokrsko in the Příbram district of Central Bohemia, Czech Republic.

The Josef UEF is employed primarily for research and the teaching of students from the CTU (and other universities). Other activities include cooperation on projects commissioned by the private business sector.

The construction of the facility was inspired by similar underground training centres in other European countries and the USA. Underground facilities run by universities provide both cutting edge research techniques and a high level of practical education for students in real conditions and contribute towards closer cooperation between universities and the world of business.

1.1 HISTORY

The Josef exploration gallery was excavated as part of renewed prospecting activities which commenced in 1981. It was decided, however, that mining operations would be discontinued since ore extraction and dressing would result in the devastation of an area of natural beauty and recreational potential and consequently, in 1991, operations came to an end. In 2000, the entrance portals were plugged with concrete to prevent unauthorised access to the underground areas.

Towards the end of the 20th century, the revival of gold mining in this area was seriously considered; however, the highest concentrations of gold occur at depths of up to 300m meaning that the gold would have to have been exploited by open-pit mining. Moreover, the separation of the gold would have required the use of the environmentally unfriendly cyanide process. Consequently, commercial gold exploitation is not currently envisaged and is very unlikely in the near future.

The idea of exploiting the Josef underground gallery for scientific purposes originated as early as in 2003. Following extensive discussions and consideration of the information available, the management of the CTU gave its support to the Faculty of Civil Engineering's scheme to establish the Josef UEF as a CTU multidisciplinary workplace. Unlike a number of foreign underground laboratories, the CTU facility is not single topic-oriented; the size of the Josef underground gallery and its geological diversity allow the participation of a wide spectrum of those interested in experimental research.

1.2 DESCRIPTION OF THE JOSEF GALLERY

The Josef exploration gallery runs in a NNE direction across the Mokrsko hill rock massif. The total length of the main drift is 1836m, with a cross-section of 14–16m^2. The overlying rock thickness is 90–150m. Two parallel tunnels lead from the entrance portals, each having a length of 80m and a cross-section of 40m^2. The main exploration gallery is connected to various exploration workings by a number of insets which follow ore formations and provide access to two further levels. The total length of the galleries is approximately 9km; 90% of the breakings are not fitted with linings. The end of the main gallery is connected to the ground surface by means of an unsupported 110m vent.

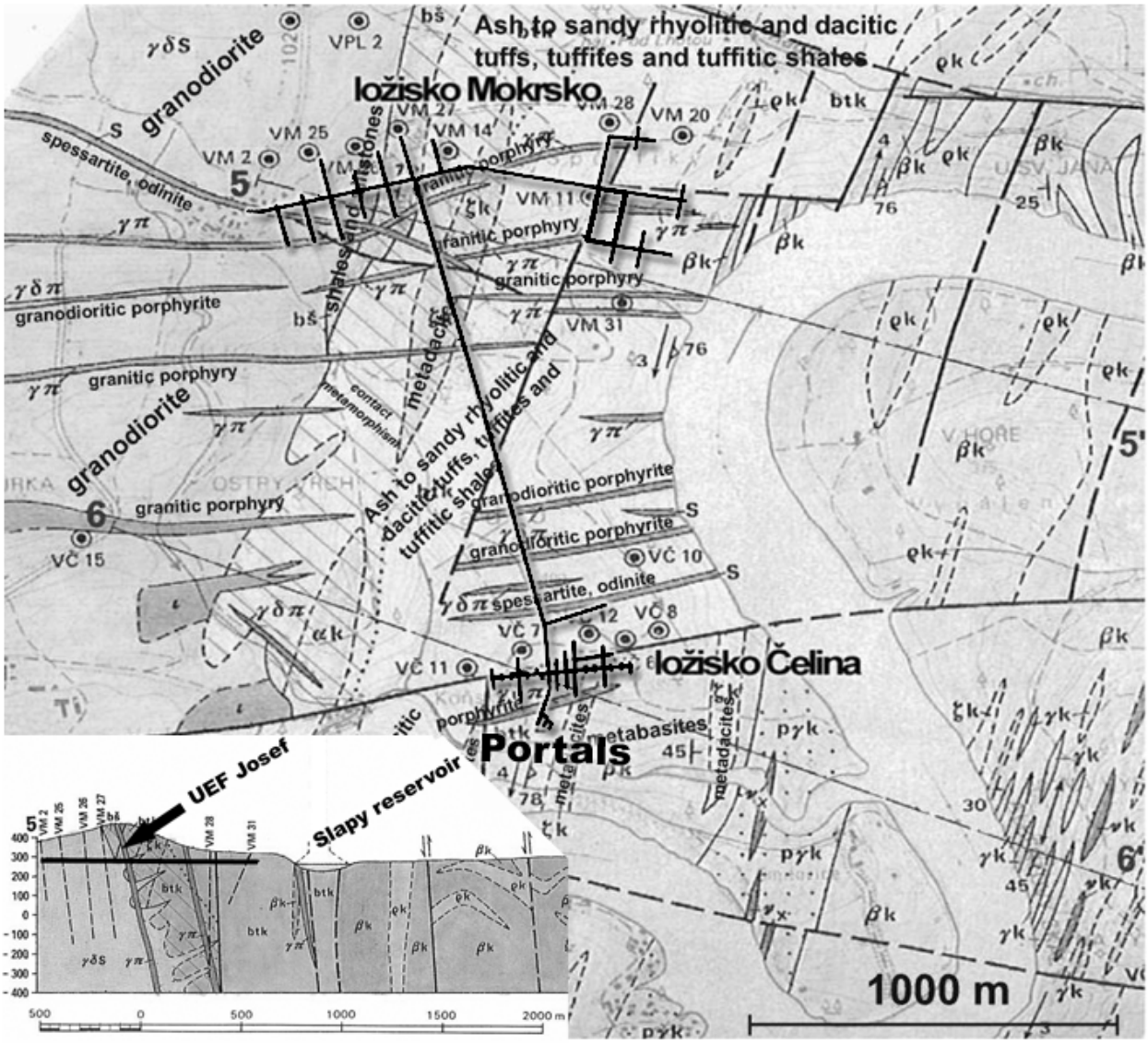

Figure 1 - Geology of the Josef Gallery (based on a map composed by the Czech Geological Survey 1991)

1.3 GEOLOGY

The Josef gallery was originally excavated as part of the exploration of the Psí hory gold-bearing district, which is located mainly in the Proterozoic Jílovské belt, in rock of more than 600 million years old (Morávek, 1996). Central Bohemian Pluton granitoid rocks subsequently penetrated these rocks during the Variscan orogenesis.

In the Psí hory area, the Jílovské belt consists of volcanic rocks of both basic and acidic composition (basalts, andesites, dacites and rhyolites) in the central area with subvolcanic plagiogranites at its eastern edge and gold bearing acidic to intermediate tuffs.

The overburden consists of a volcanic-sedimentary formation consisting mostly of tuffs and tuffitic shales. To the west, the Psí hory mining district extends to the margin of the biotitic-amphibolic granodiorite of the Central Bohemian Pluton.

Towards the end of the 20th century the Psí hory district was systematically explored in connection with the potential revival of gold mining. There are two gold-bearing deposits in the area – the Čelina deposit, mined as early as in the middle ages, and the Mokrsko deposit. The

Čelina deposit and the eastern Mokrsko ore-zone are situated in the tuffs and vulcanites of the Jílovské belt. Most of the western Mokrsko ore zone lies in the granodiorite of the Central Bohemian Pluton.

The gold reserves in this area are some of the richest in Europe. According to recent estimates, local deposits contain up to 130t of the precious metal. Gold mineralization is concentrated in quartz veins and is mostly very fine grained. The average gold content in the rock is no higher than 2g/t (Morávek, 1996), which explains why the Mokrsko deposit escaped the notice of medieval miners; its potential was only fully recognized as late as in the nineteen eighties.

Geological diversity is one of the great advantages of the Josef UEF. There are two basic geological formations each with a very different history and contact zones. Moreover, each of the formations exhibits different physical and material properties which change in character towards the contact zone and which feature a variety of local fracture zones and intrusions. This provides a high level of flexibility with regard to choosing the right place for conducting experiments depending on the conditions required for example fracture systems, rock stability, rock strength, mineralogy, etc.

Rock characterisation

This section both describes in greater detail the geological characteristics of the two main sections of the underground complex (Čelina and Mokrsko) and summarises the results of the geological survey on the basis of which test locations were chosen and the rock quality of each location assessed using a number of rock mass classification systems.

1.4 GEOLOGICAL CHARACTERISTICS

The Josef gallery is located in an area characterised by Psí hory auriferous deposits the geological structure of which consists of volcanic rock (basalts, andesites, rhyolites), sedimentary rock (hornfels) and their combinations (tuffs, tuffites), characterised by younger intrusive rock types (granodiorites, albitic granites).

1.4.1 The Čelina mining district

Introduction

Gold deposits are located in the southern part of the Psí hory mining area (Morávek, 1992); the host rock consists of contact metamorphosed rock – originally sedimentary volcanic rock (complex of different rock types: tuffs, with acidic to basic lava settings, at deeper level plagiogranites).

Summary

- Genetic model – hydrothermal – metamorphic
- The source of the material – Upper Proterozoic and Lower Paleozoic volcanic-sedimentary complexes with bimodal volcanism
- The energy source – thermal gradient accompanying regional metamorphism or associated with granitoid intrusion, granitisation and the assimilation of source area rocks.
- The character of the fluids – hydrothermal-metamorphic (with the possible presence of magmatic fluids).
- The concentration of gold decreases with depth.
- The distribution of stratiphorm gold is bonded with tuffs and disseminated Au grains with steep (vertical) quartz veins.
- Information on deposits is taken from different sources: drill holes are 500m deep, the gallery is 60 – 90m below the surface.

Petrography

The geological structure is represented on the mining map at a scale of 1:200, sheet: Krásná Hora 1 – 0/41 – 23 (Appendix 1). The petrography is relatively monotonous with a number of different volcanic elements and a variety of tuffs and lava flows (intermediate or unrecognised). The rock is highly fractured. The host rock is traversed by a nearly vertical (steep) system of quartz veins.

Hydrology

The main moisture collector consists of the rock joint system. This location does not have a significant supply of underground water; the rock is merely damp.

1.4.2 The Mokrsko mining district

Introduction

The Mokrsko gold deposit forms part of the Psí hory district, located in the central part of the Jílové belt and the Slapy apofysis (Morávek, 1992). The gold mineralisation of veins up to the sheeted vein (”stockworks”) is related to the east – west trending dilatation zones intersecting the volcanic – sedimentary complex and a marginal part of the granodiorite of the Central Bohemian pluton. The Mokrsko (as well as the Čelina) deposit was explored in detail. The gold mineralisation zone which is made up of a network of steep parallel veinlets up to thicker veins, attains a thickness of several tens of meters up to 200m in the Mokrsko West deposit situated in granodiorite.

The gold mineralization has been interpreted as being of high temperature (300 – 420°C) without the alteration of the adjacent rock. The vertical zoning of the gold mineralisation is indicated by a decrease in Au and an increase in W (scheelite) in the downwards direction.

Summary

- Genetic model – hydrothermal – metamorphic.
- The source of the material – Upper Proterozoic and Lower Paleozoic volcanic-sedimentary complexes with bimodal volcanism.
- The energy source – thermal gradient accompanying regional metamorphism or associated with granitoid intrusion, granitisation and the assimilation of the source area rock.
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- The concentration of gold decreases with depth.
- The distribution of stratiphorm gold is bonded with steep (vertical) quartz veins.
- Information on deposits is taken from different sources: drill holes are 500m deep, the gallery is 60 – 90m below the surface.

Petrography

The geological structure is represented on the mining map at a scale of 1:200. The petrography is relatively monotonous i.e. grey and green-grey granodiorite (Sázava type - Upper Devonian) with fine to intermediate crystallisation; the rock is highly fractured. The host rock is traversed by a nearly vertical (steep) system of quartz (calcite, barite) veins.

Hydrology

The main moisture collector consists of the rock joint system. This location does not have a significant supply of underground water; the rock is merely damp. The only exceptions are those locations situated close to older drill holes.

1.5 SELECTION AND CHARACTERISATION OF TEST LOCATIONS

Several sites with different geological conditions were identified for gas injection testing purposes. Two sites were selected in the Čelina area (Čelina 1, Čelina 3) and two in the Mokrsko area (Mokrsko 1, Mokrsko 2). Core drilling was performed at each of the sites which were subsequently geologically mapped in detail. Rock classification values were then determined based on information provided by the geological survey.

Two locations were mapped in the Čelina area the first of which was in a relatively non-intensively tectonised zone - cross cut (drift) SCH-Z/JP9 between the 67 and 74 metre points (Čelina 1) , and the second close to a highly tectonised area - cross cut SCH-Z/SP11 between the 116 and 126 metre points (Čelina 3).

Two locations were tested in the Mokrsko area before drilling, the first of which was in relatively homogenous (monotonous) granodiorite (Central Bohemian Massif - Slapy apofysis) cross cut (drift) M-SCH-Z/SP-35, between the 70 and 92 meter points (Mokrsko 1) and the second in short drift M-SCH-Z/SP-19 (the interface between a volcanic-sedimentary complex – tuffs and tuffites and the Central Bohemian Pluton – granodiorite) (Mokrsko 2).

For additional information purposes, the sides of the drifts were mapped (Appendix 4); the strike and dip (Figure 3) of foliations (unknown) and the joint system (cracks) were measured. The results are shown in Appendix 3 in the form of tectonograms and stereonets. General geological information (petrography, tectonics – major tectonic phenomena) is recorded in geological map form (Appendix 1).

With regard to the Čelina 1 site, a number of dominant foliation systems with a north - south strike and dip between 90 and 45 degrees, as well as a vertical south east – north west system were discovered; the rest of the site appeared to be random in nature. The Čelina 3 site is similar with a major system of foliation (joints or “layering”) pushing slightly north east – south west with a dip of around 50 degrees, and a second system west - east with a range of dip from 70 to 30 degrees.

In neither of the sites could the exact origin of the foliation be determined; it must be assumed either a vertical system of cleavage or original bedding.

In the Mokrsko 1 stereonet three dominant systems of jointing (foliation) were recognised. System 1 - strike west - east with steep dip (180/80). System 2 - strike north west - south east with steep dip (80/85). System 3 (slightly diffuse) - strike north west - south east, close to horizontal dip (280/35). Two main joint systems, both with a steep dip, were discovered at the Mokrsko 2 site.

Figure 2 - Analysis of drill cores

Figure 3 - Measuring of discontinuities

1.6 ROCK MASS CLASSIFICATION

In order to assess the quality of the rock mass at selected locations, rock mass classification systems were used. Rock mass classification systems are widely used for the evaluation of the stability of underground engineered structures. In this case the following index classifications were used: **RQD** (Rock Quality Designation), **Q** method, **RMR** (Rock Mass Rating), **RMi** (Rock Mass Index). These systems include a number of important parameters, such as discontinuities, which are highly relevant to rock mass gas conductivity and therefore will prove very useful for the later study of migration. The classification input parameters were determined based on the survey and the analysis of drill cores (Figure 2).

Table 1 shows the input parameter values of the various classification systems and the basic equations for the calculation of the indices. Table 2 shows the overall results of the classification indices and a verbal rating of the quality of the rock mass.

Table 1 - Calculation of classification indices

		Čelina 1	Čelina 3	Mokrsko1
RQD (from drill core)		**58**	**46**	**69**
joint set number	Jn	12	15	12
joint roughness number	Jr	1,75	3	1,42
joint alteration number	Ja	0,92	2,5	0,95
joint water reduction factor	Jw	1	1	1
stress reduction factor	SRF	1	1	1
Q		**9,2**	**3,7**	**8,6**

$$Q = \frac{RQD}{Jn} \times \frac{Jr}{Ja} \times \frac{Jw}{SRF}$$

strength of intact rock	A	12	12	7
RQD	B	13	8	13
spacing of discontinuities	C	10	8	10
condition of discontinuities	D	23	18	23
ground water	E	15	15	15
discontinuity orientations	F	-2	-2	-2
RMR		**71**	**59**	**66**

$$RMR = \sum (A + B + C + D + E - F)$$

compressive strength	6c	122	122	93
block volume	Vb	0,024	0,00215	0,033
joint roughness factor	jR	1,75	3	1,42
joint alteration factor	jA	0,92	2,5	0,95
joint length	jL	1	1	1
joint conditions	jC	1,902	1,200	1,495
	D	0,325	0,357	0,341
reducing effect of the joints	jP	0,082	0,024	0,076
RMi		**10,0**	**3,0**	**7,1**

$$jP = 0{,}2\sqrt{jC} \times V_b^{\,D}$$

$$jC = \frac{jR \times jL}{jA}$$

$$D = 0{,}37\ jC^{-0{,}2}$$

$$RMi = \sigma_c . jP$$

Table 2 - Results of rock mass classification

Locality (Borehole)	RQD		Q		RMR		RMi	
Čelina 1	58	fair	**9,2**	fair	**71**	good	**10,0**	moderate - high
Čelina 3	46	poor	**3,7**	poor	**59**	fair	**3,0**	moderate
Mokrsko 1	69	fair	**8,6**	fair	**66**	good	**7,1**	moderate

Field Installation

This section describes the preparatory work performed before in-situ permeability testing could begin. Based on the detailed geological survey, locations were selected in which boreholes were then drilled. In addition, the in-situ experimental equipment was set up and tested.

At the beginning of the project the Mokrsko deposit was not yet fully accessible and preparations for full access (i.e. clearing, installation of ventilation and reinforcement) were underway. Therefore the Čelina area (tuffites) was used for the initial testing of the experimental equipment. Following the opening of the Mokrsko area of the Josef facility, experimental work commenced in the crystalline rock section which is of particular interest to the FORGE project.

1.7 BOREHOLE DRILLING

Boreholes with a diameter of 56.5mm were drilled in selected locations (Figure 4; Table 3). The direction and length of the boreholes can be seen on the mining maps (Appendix 1). The logging of core samples obtained from the boreholes (Figure 5) was carried out as the drilling work progressed. The drill cores were described according to both their petrography and RQD classification (Appendix 2).

Table 3 - Injection boreholes

Borehole	Cross cut (drift)	Chainage	Borehole length
Čelina 1	SCH-Z/JP9	72m	15.0m
Čelina 3	SCH-Z/SP7	end of drift	22.2m
Mokrsko 1	M-SCH-Z/SP35	84m	20.4m
Mokrsko 2	M-SCH-Z/SP19	5m	19.7m

Figure 4 - Borehole drilling at the Čelina 1 site

Figure 5 - Logging of a drill core

1.8 PREPARATION OF TEST EQUIPMENT

1.8.1 Description of the equipment

For the purposes of in-situ testing, the Centre of Experimental Geotechnics acquired a special custom-made set of test equipment.

This equipment, specially designed for gas injection testing, consists of a probe, measurement apparatus, a gas reservoir and a compressor. The gas is injected into the borehole which is sealed by means of a "packer" system (Figure 6) consisting of a single packer or a double packer; compressed air is used as the gaseous medium and is supplied by means of a high pressure compressor (air pump). The flow of air is ensured through the use of a pressurised cylinder and is controlled by measuring apparatus in the borehole. The cylinder serves as a compressed air reservoir and helps to reduce compressor running time. The whole assembly is shown in diagram form in Figure 7.

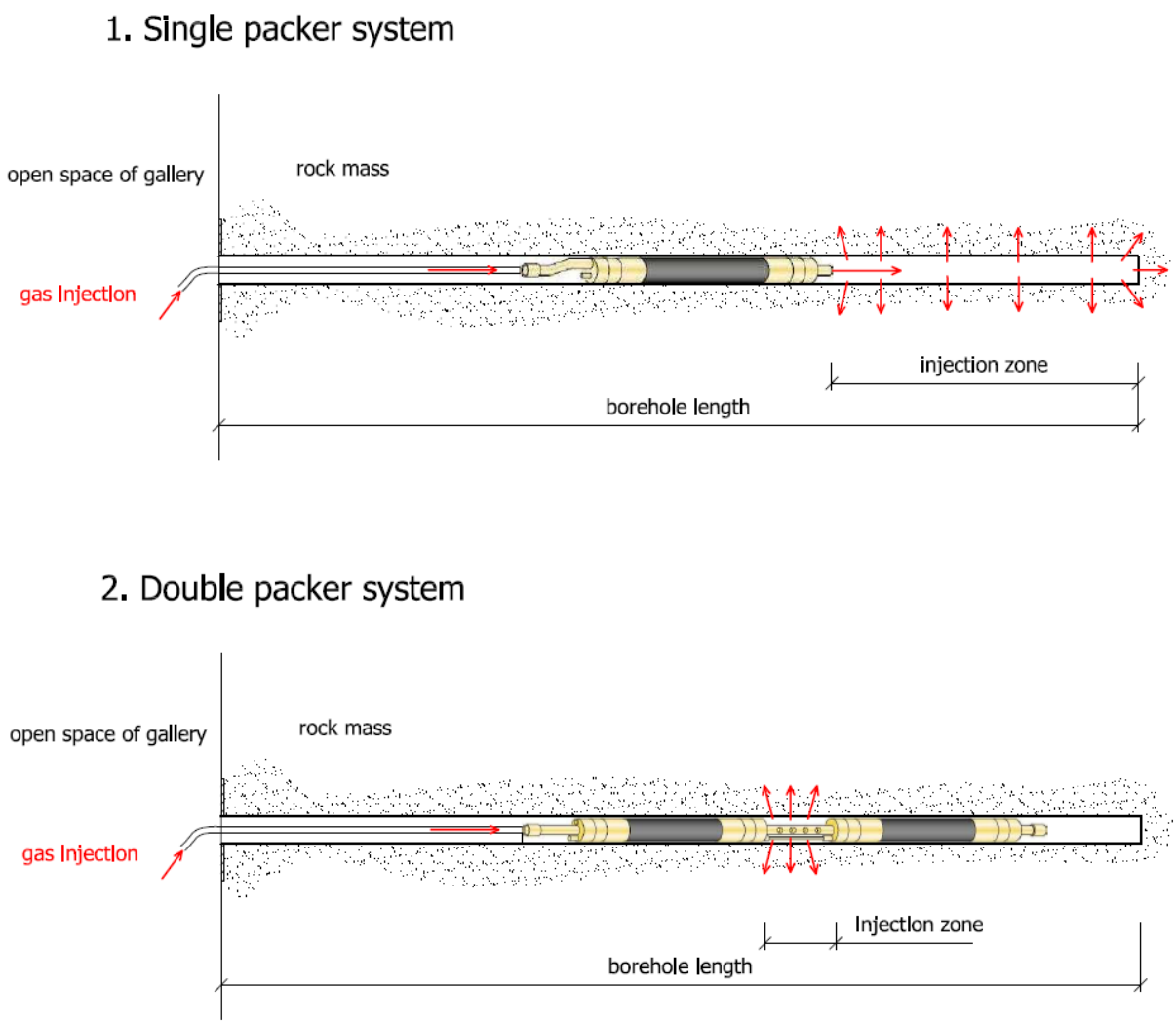


Figure 6 - Packer systems

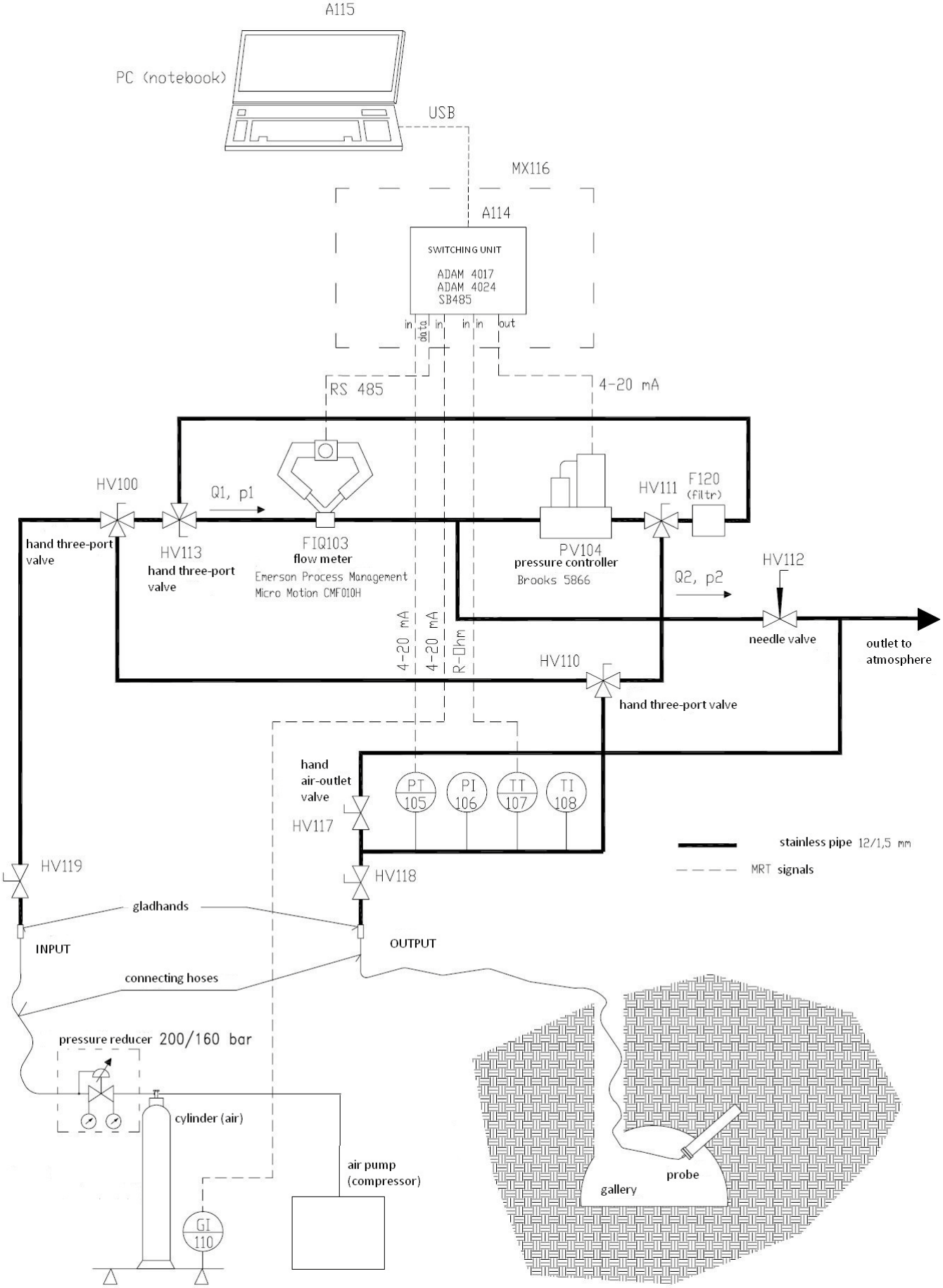


Figure 7 - Scheme of equipment

1.8.2 Measuring apparatus

The unique measuring apparatus (Figures 8 and 9) was made especially for the CEG and consists of high-pressure equipment for the in-situ measurement of the permeability of the rock mass. It is designed to function as a mobile measuring station and features gas pressure level control and the automatic registration of pressure, temperature and gas volume. The equipment allows the recording of parameter values at a minimum time interval of two seconds. The control and recording software runs on a laptop using the Windows operating system.

Figure 8 - Measuring apparatus

Figure 9 - Set of test equipment

1.8.3 Testing of equipment in the laboratory and in-situ

The measuring equipment was tested first in the laboratory (Figure 10) and subsequently in the prepared boreholes in the Čelina and Mokrsko sections of the facility (Figure 11).

The measuring apparatus allows the performance of the following types of test:

• CHIT (Constant Head Injection Test) – the testing methodology is based on pressurising the borehole at the prescribed pressure level during which pressure is maintained by varying the flow of the medium.

• PDT (Pressure Drop Test) – the test procedure consists of pressurising the borehole to the prescribed pressure level and then subtracting the subsequent drop in pressure.

• Measurement of air flow on output - this test involves the comparison of the amount of air flowing into and then back from the borehole.

The first tests were carried out in the Čelina boreholes (tuffites) and then, following the extension of the Josef facility, testing was shifted to the crystalline rock of the Mokrsko granodiorite.

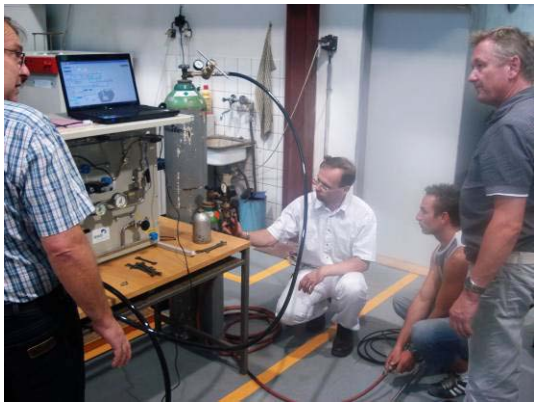


Figure 10 - Testing of equipment in the laboratory

Figure 11 - Testing of equipment in-situ

Conclusion

The Josef UEF provides an excellent opportunity for in-situ research and full-scale physical modelling. The key advantages of the facility include: ideal location in the vicinity of Prague, variable geological conditions, excellent infrastructure including a high speed data network, and a university background. The Josef UEF has been designed to be a multidisciplinary workplace. Unlike a number of foreign underground laboratories, the CTU's Josef facility is not single topic-oriented; the size of the Josef underground gallery and its geological diversity allow the participation of a wide spectrum of those interested in experimental research.

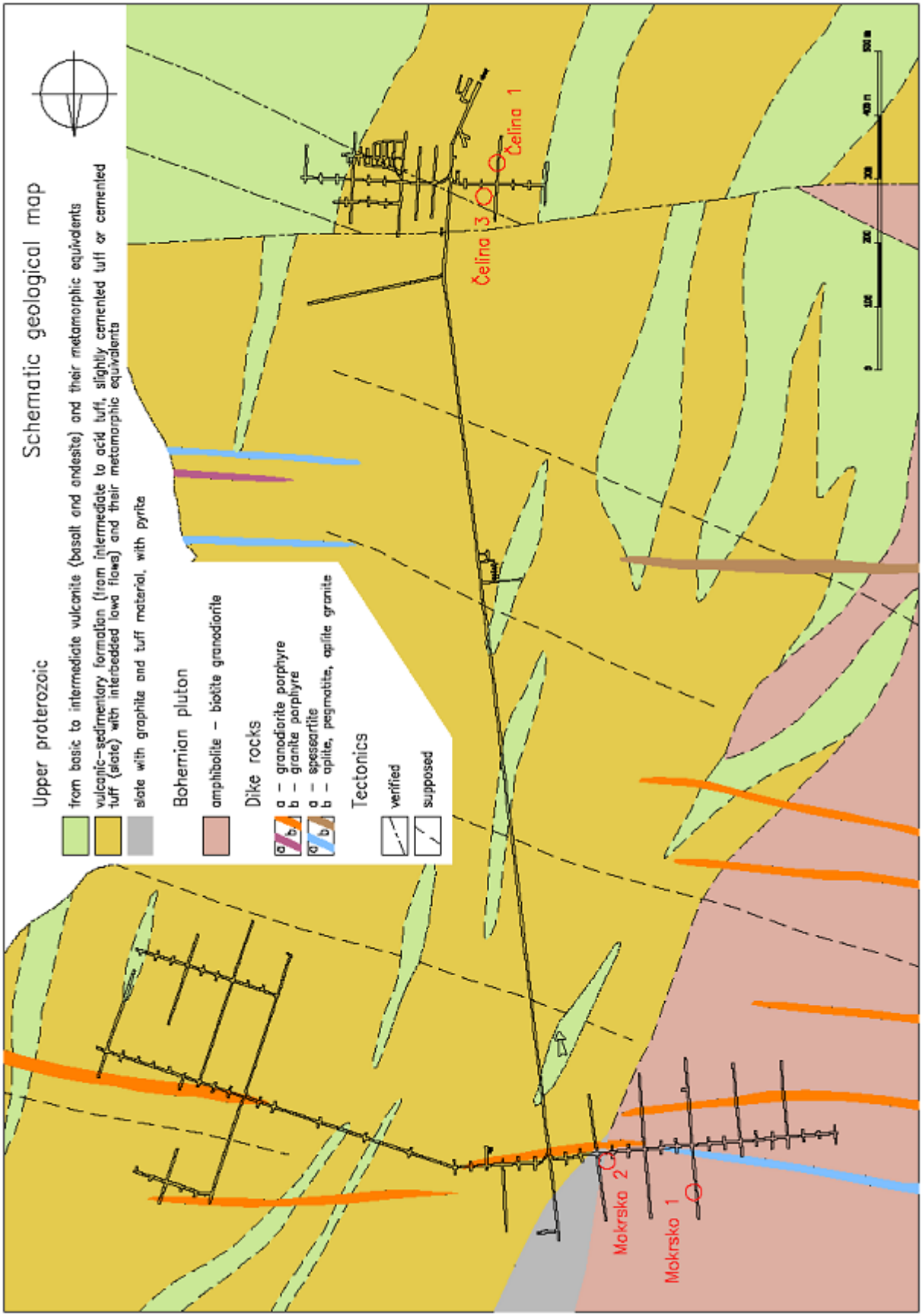
In order to select locations for in-situ testing, a detailed geological survey was carried out. Consequently, in-situ test locations were selected in the Čelina and Mokrsko areas of the facility which were then mapped in detail and assessed using a number of rock mass classification systems. Preparation work continued with the exhaustive testing of the special equipment to be used for measurement purposes.

Both the equipment and the test locations are ready for the performance of the necessary tests.

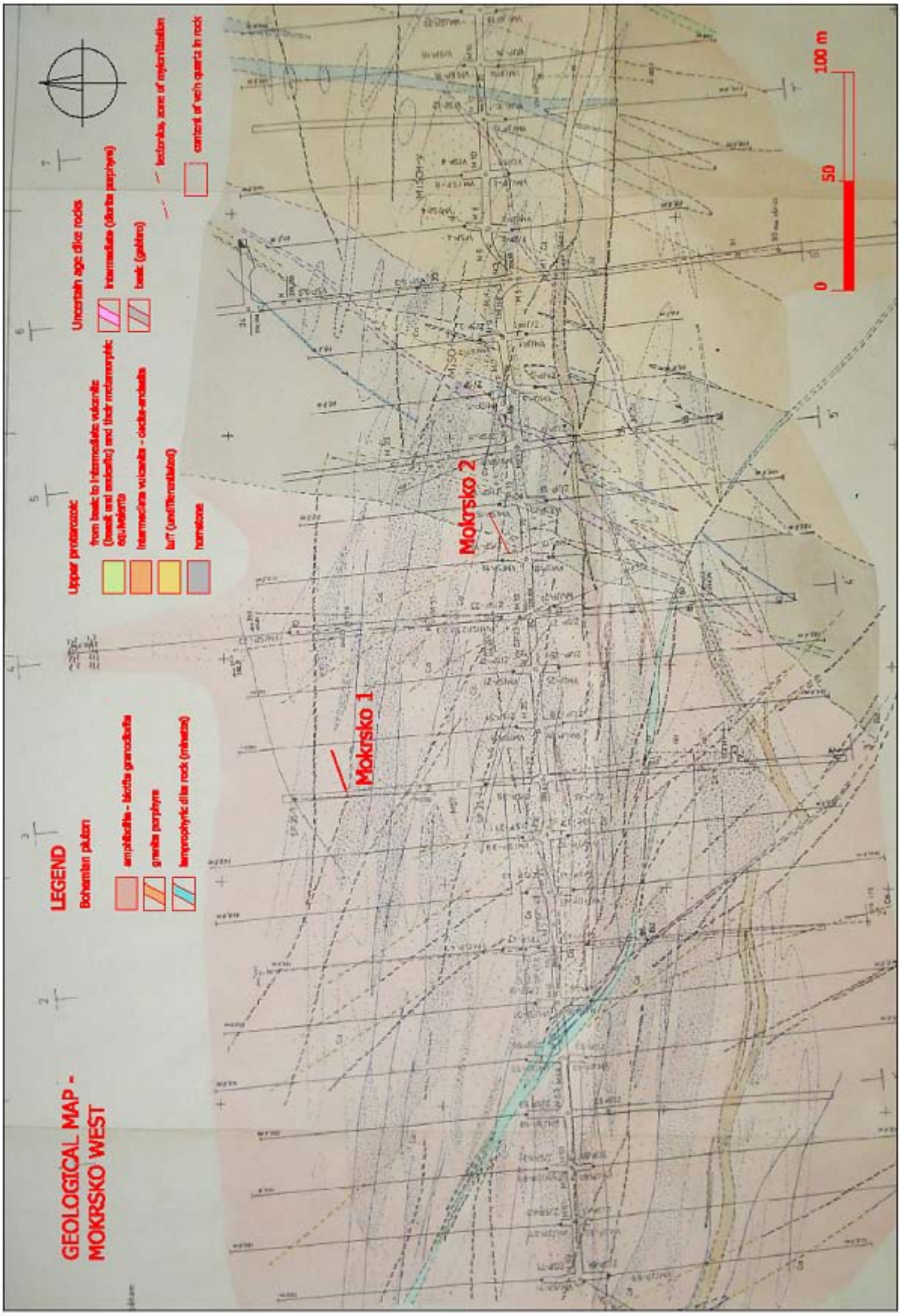
Finally it is worth noting that the experimental team considered using some of the old boreholes drilled during the exploration of gold deposits and/or boreholes situated below groundwater level. However this was temporarily rejected since such boreholes have been sealed by means of cement plugs of unknown length which would be difficult to remove.

Appendix 1 Geological maps

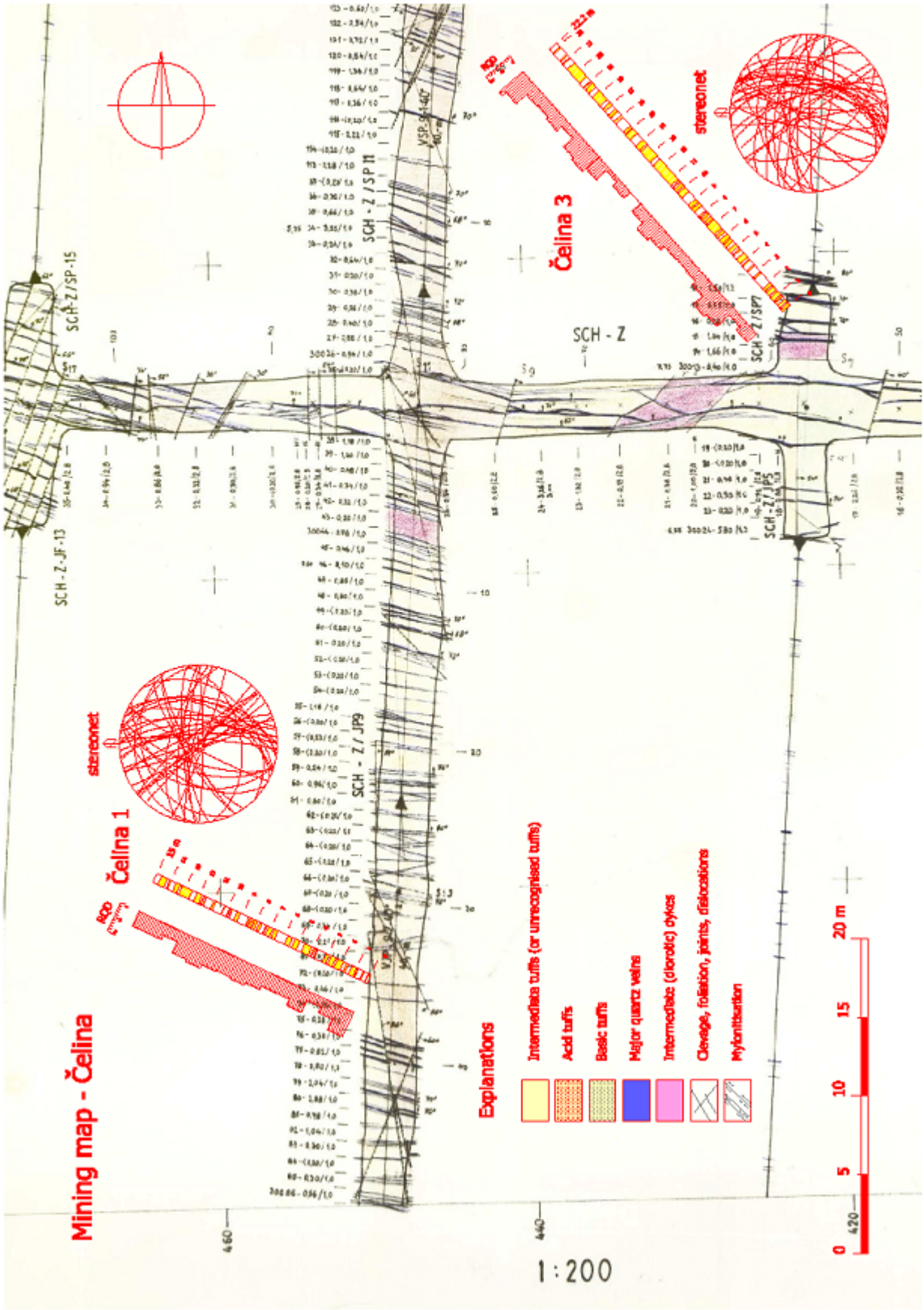
SCHEMATIC GEOLOGICAL MAP



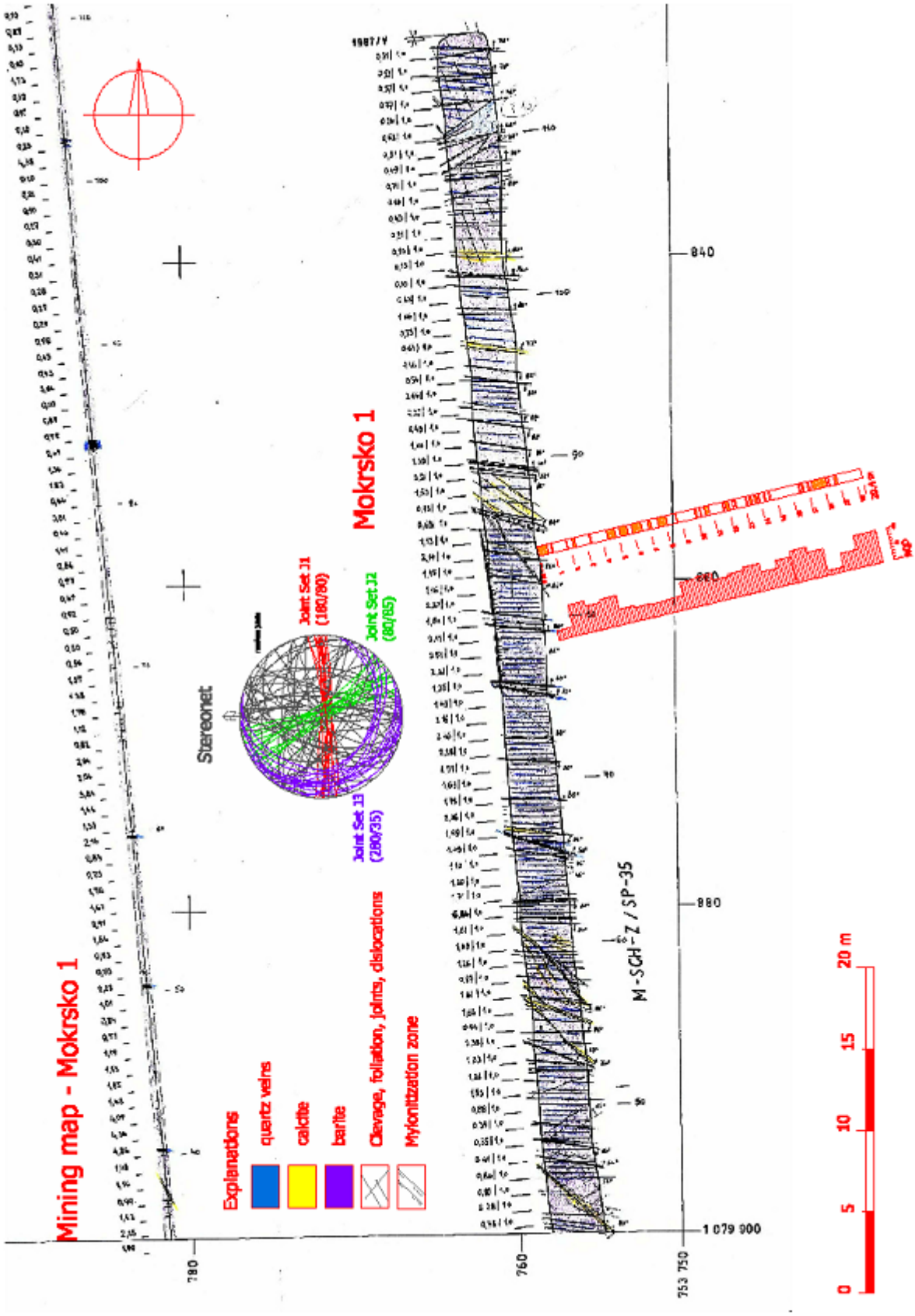
GEOLOGICAL MAP - MOKRSKO WEST



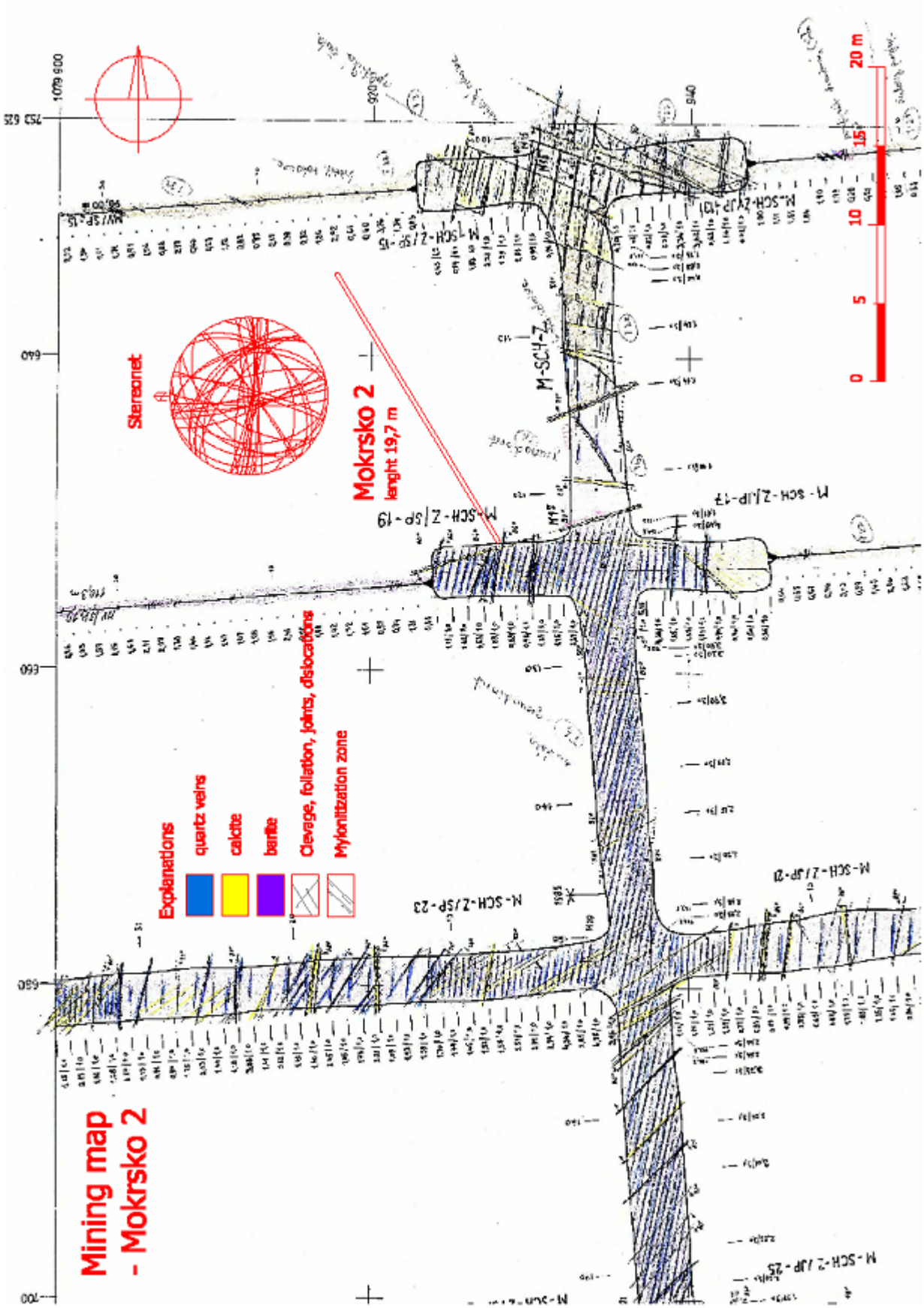
MINING MAP - ČELINA



MINING MAP - MOKRSKO 1



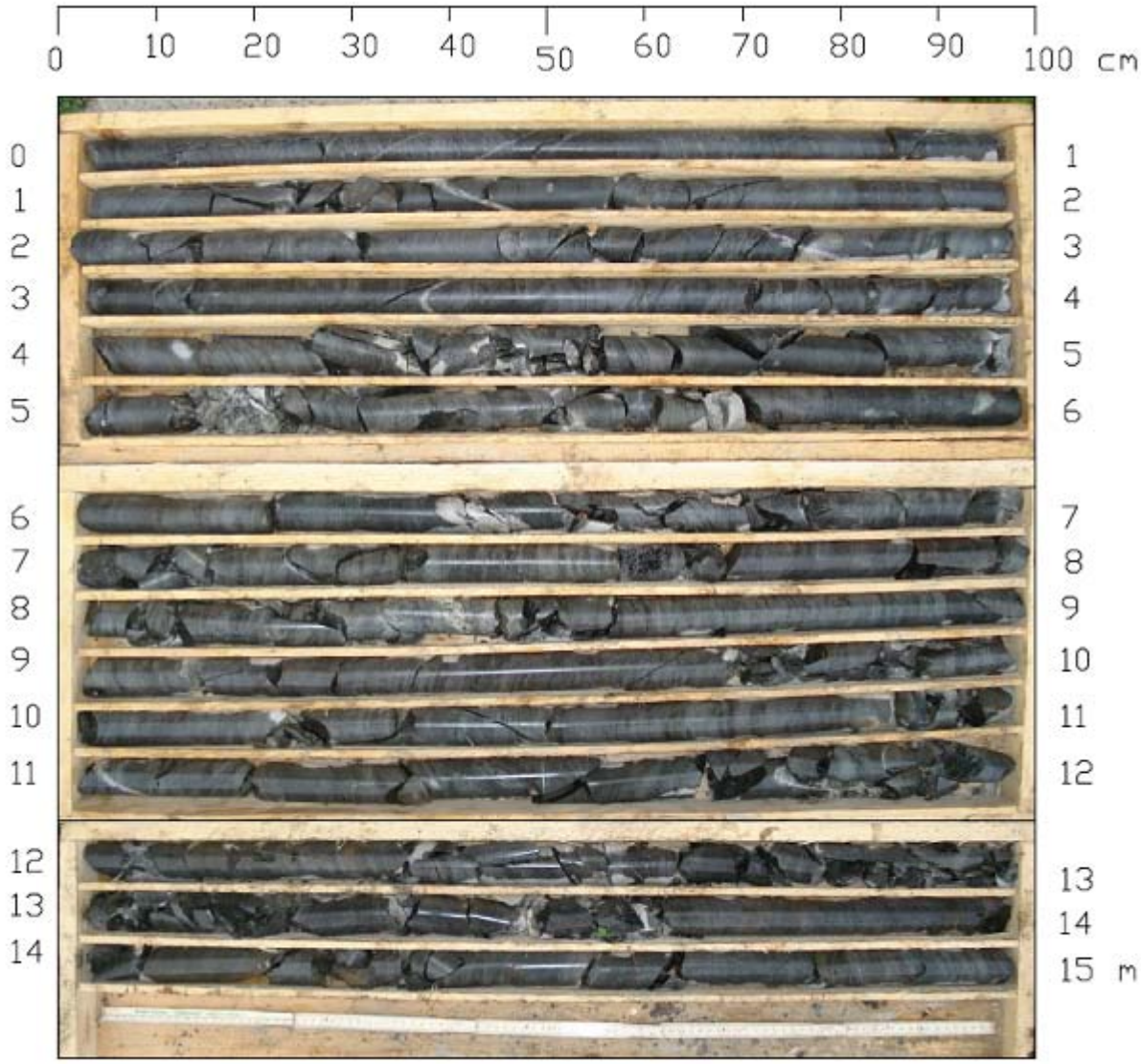
MINING MAP - MOKRSKO 2



Appendix 2 Documentation of drill cores

PHOTO DOCUMENTATION OF DRILL CORES

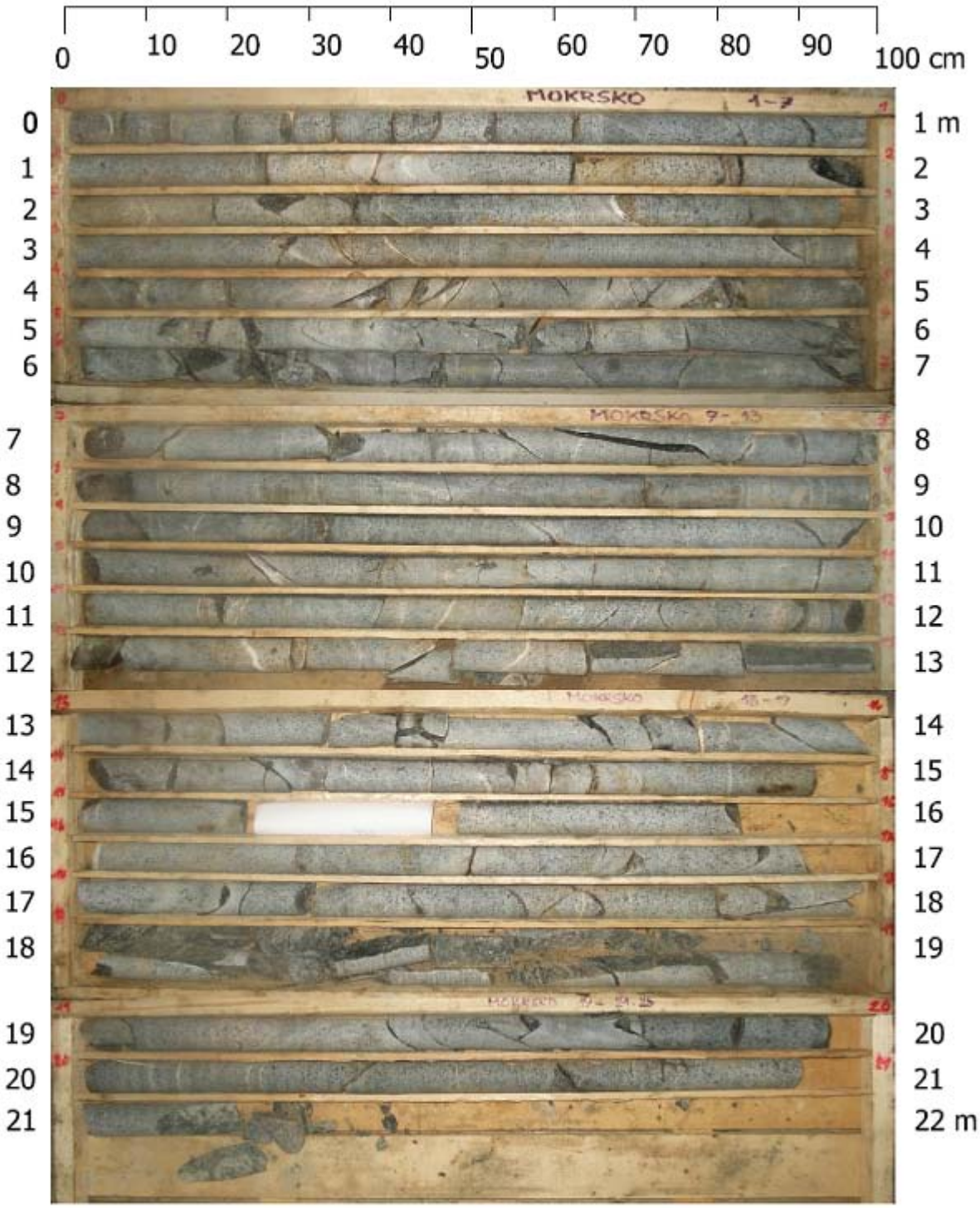
ČELINA 1



ČELINA 3

0 10 20 30 40 50 60 70 80 90 100 cm
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22
0 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23

MOKRSKO 1

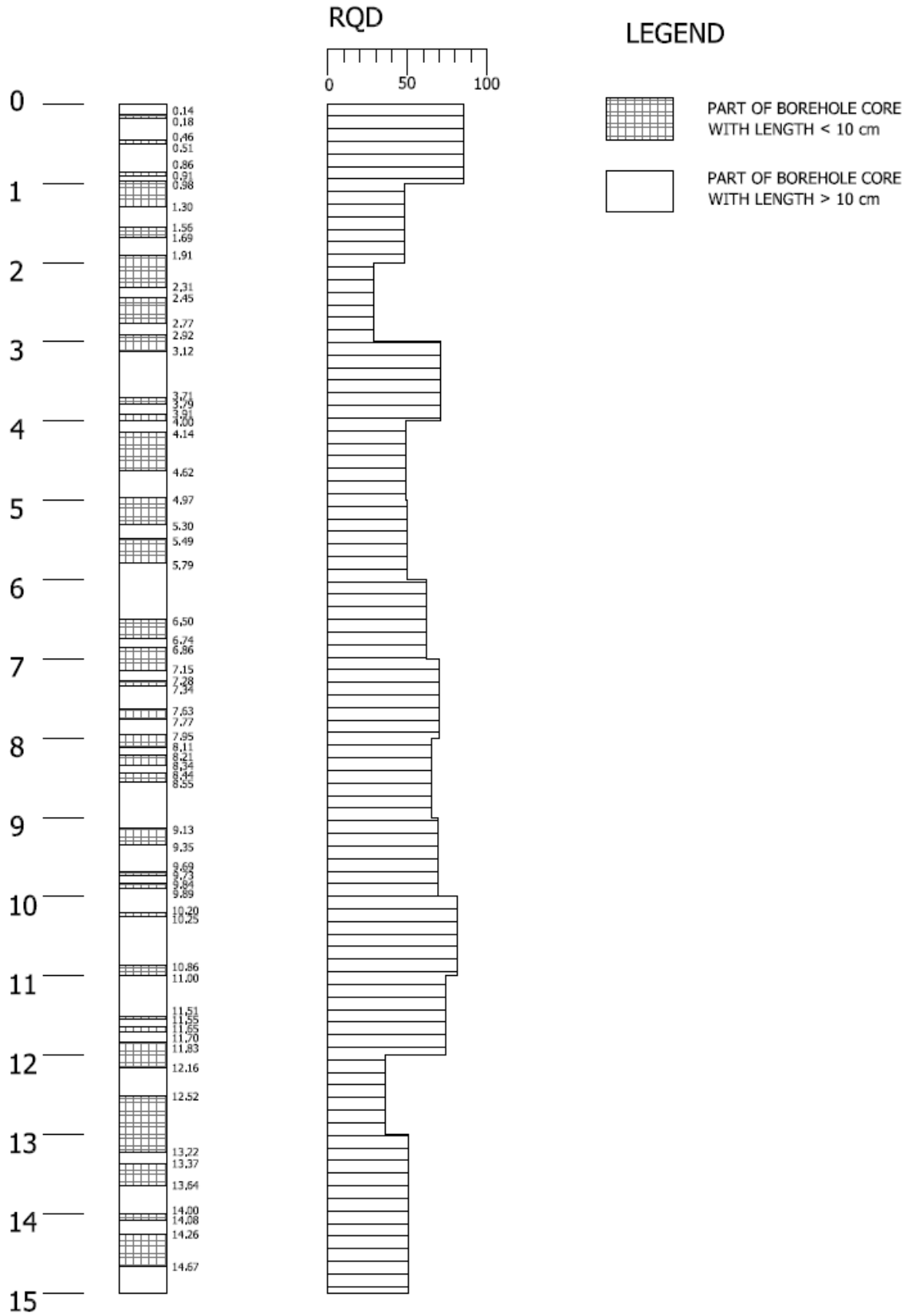

0
10
20
30
40
50
60
70
80
90
100 cm
MOKRSKO
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
1 m
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22 m

MOKRSKO 2

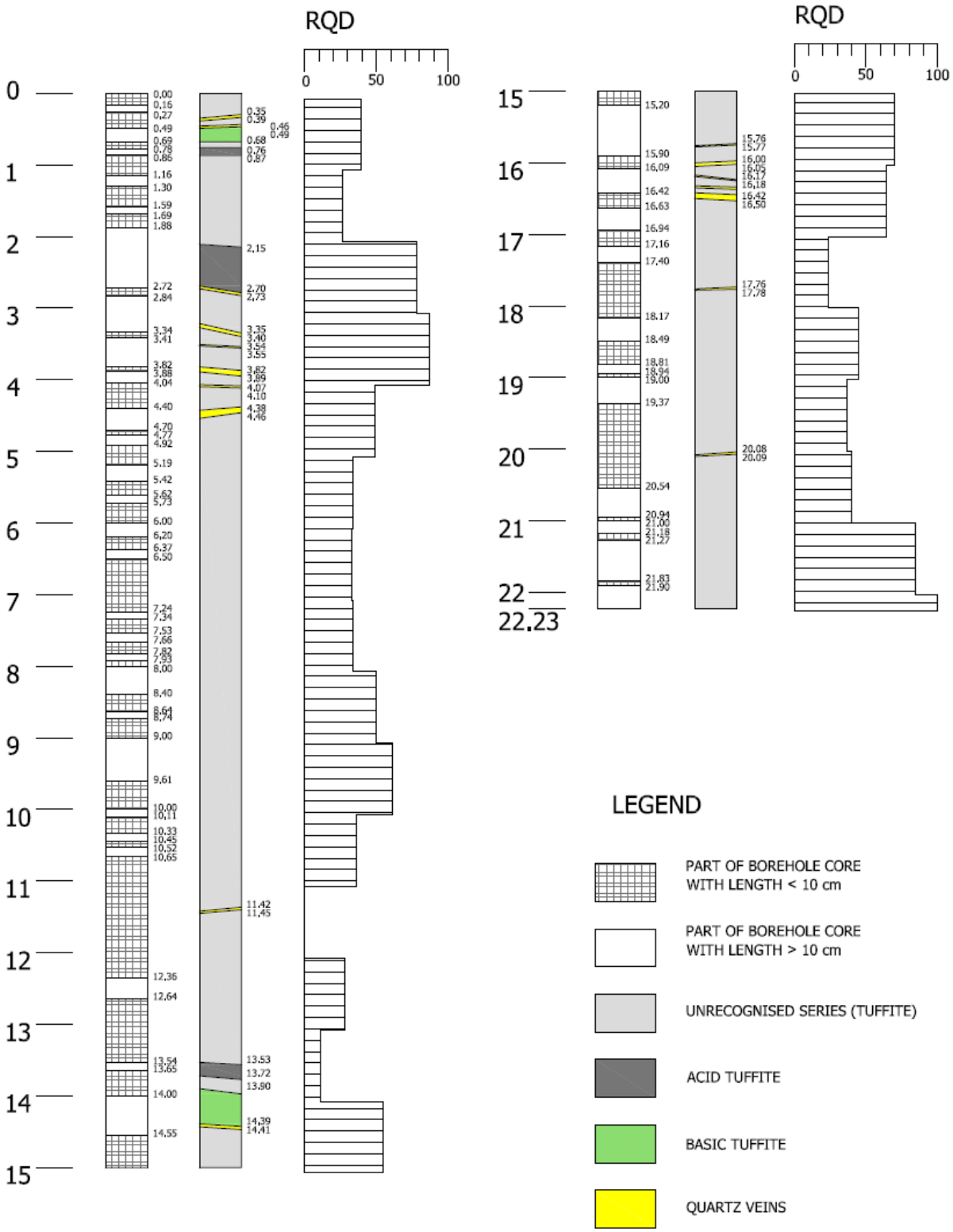
0
10
20
30
40
50
60
70
80
90
100 cm
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
1 m
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21 m

BOREHOLE DOCUMENTATION

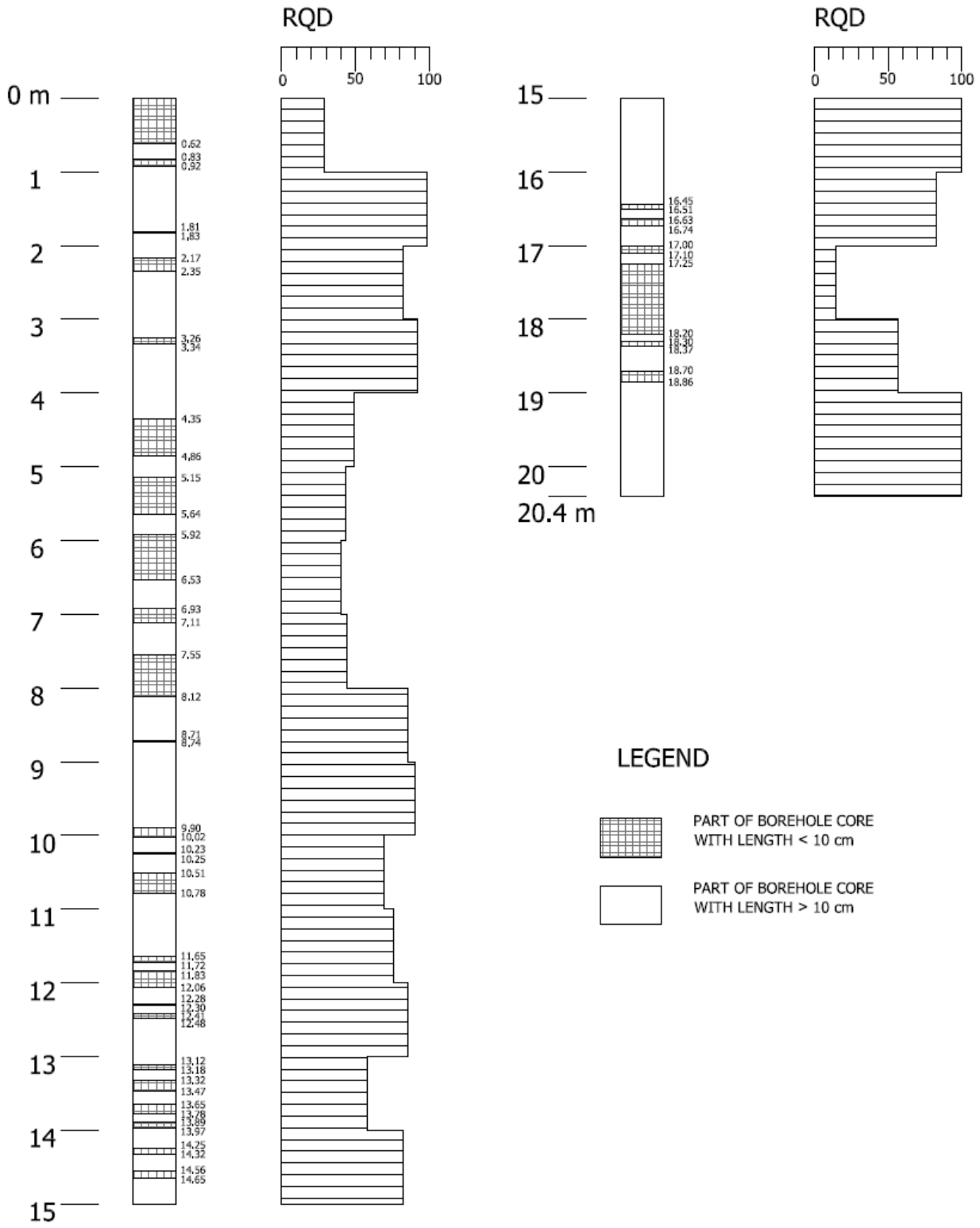
ČELINA 1



ČELINA 3


RQD
0
50
100
RQD
0
50
100
LEGEND
PART OF BOREHOLE CORE WITH LENGTH < 10 cm
PART OF BOREHOLE CORE WITH LENGTH > 10 cm
UNRECOGNISED SERIES (TUFFITE)
ACID TUFFITE
BASIC TUFFITE
QUARTZ VEINS

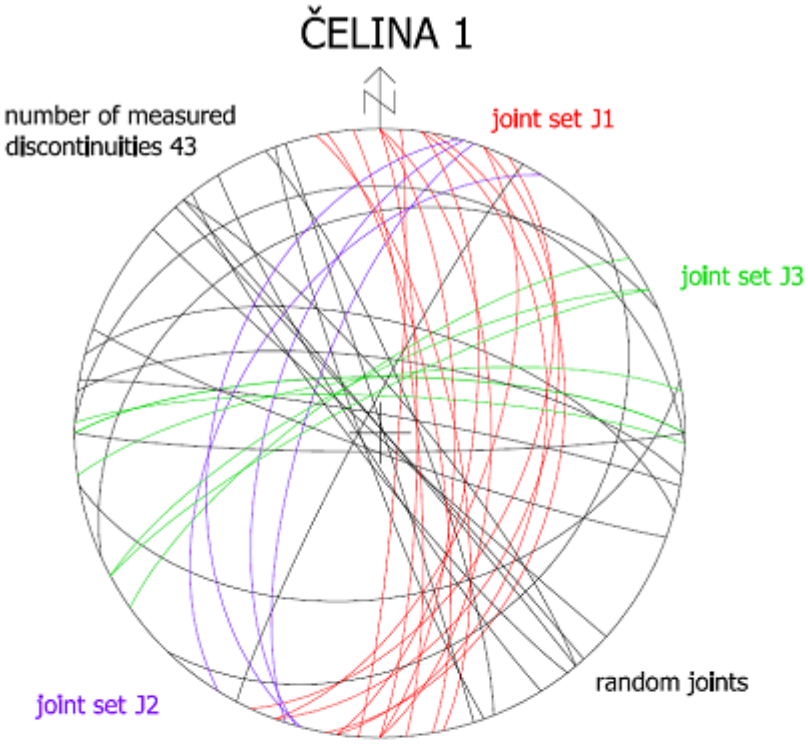
MOKRSKO 1

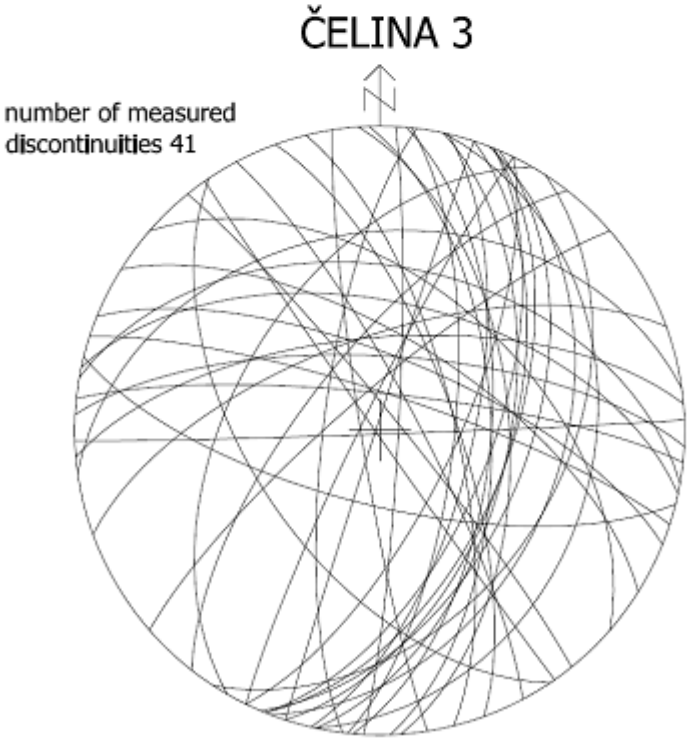

RQD
0
50
100
0 m
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
0.62
0.83
0.92
1.81
1.83
2.17
2.35
3.26
3.34
4.35
4.86
5.15
5.64
5.92
6.53
6.93
7.11
7.55
8.12
8.71
8.74
9.90
10.02
10.23
10.25
10.51
10.78
11.65
11.72
11.83
12.06
12.28
12.30
12.41
12.48
13.12
13.18
13.32
13.47
13.65
13.78
13.89
13.97
14.25
14.32
14.56
14.65
RQD
0
50
100
15
16
17
18
19
20
20.4 m
16.45
16.51
16.63
16.74
17.00
17.10
17.25
18.20
18.30
18.37
18.70
18.86
LEGEND
PART OF BOREHOLE CORE WITH LENGTH < 10 cm
PART OF BOREHOLE CORE WITH LENGTH > 10 cm

MOKRSKO 2

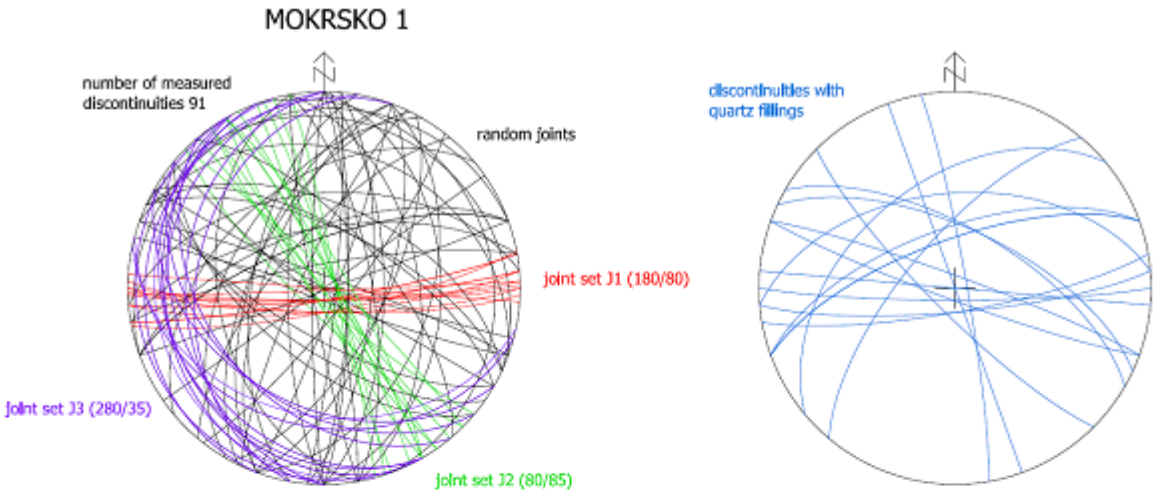
Appendix 3 Tectonic Stereonets

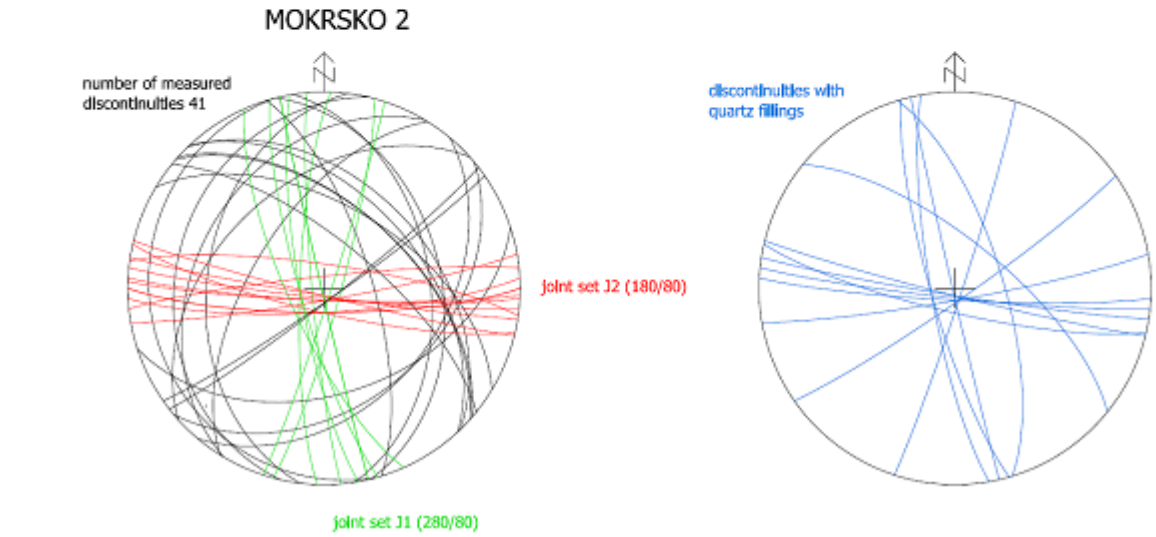
ČELINA 1, ČELINA 3





MOKRSKO 1, 2

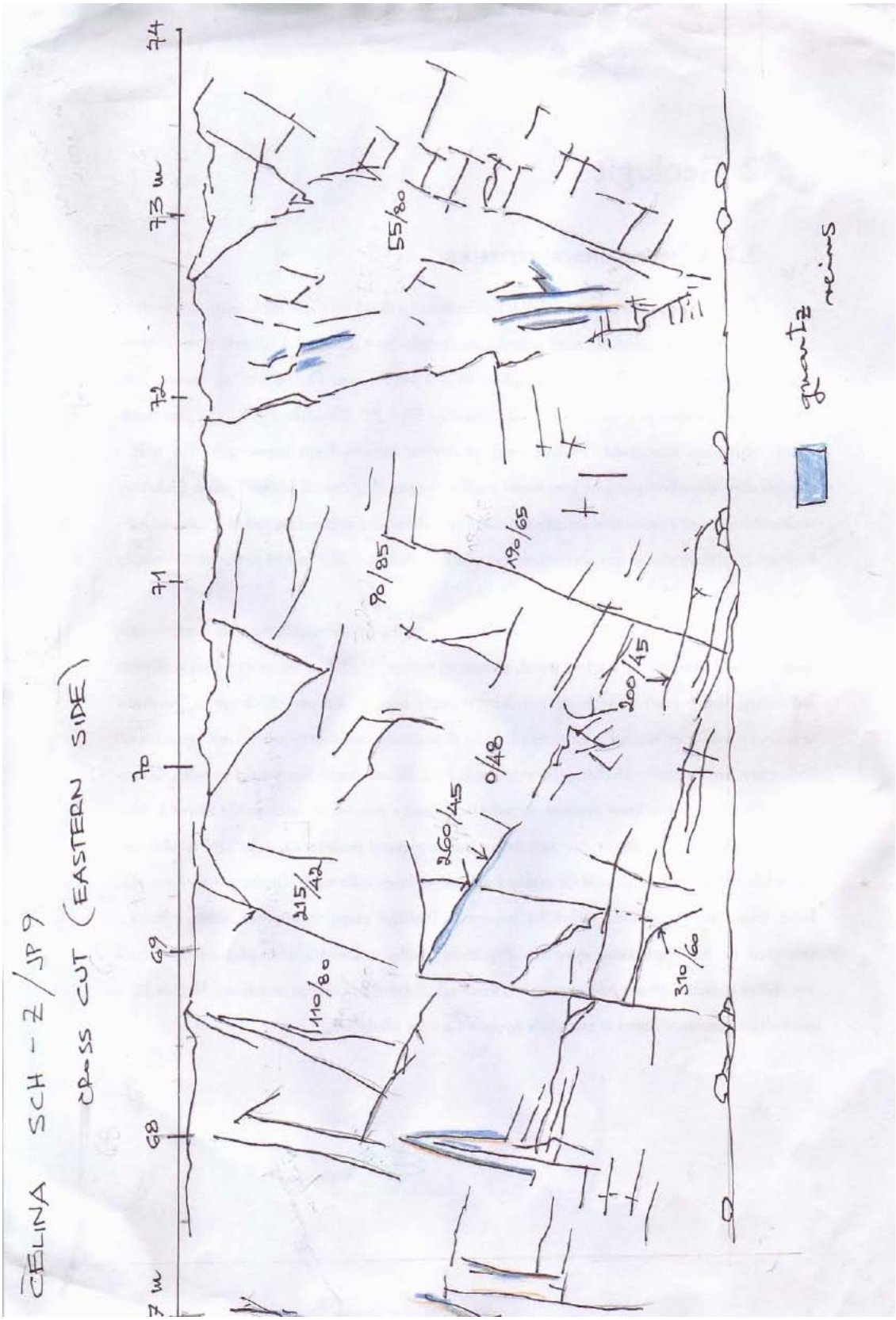

MOKRSKO 1
number of measured discontinuities 91
random joints
joint set J1 (180/80)
joint set J3 (280/35)
joint set J2 (80/85)
discontinuities with quartz fillings


MOKRSKO 2
number of measured discontinuities 41
joint set J2 (180/80)
joint set J1 (280/80)
discontinuities with quartz fillings

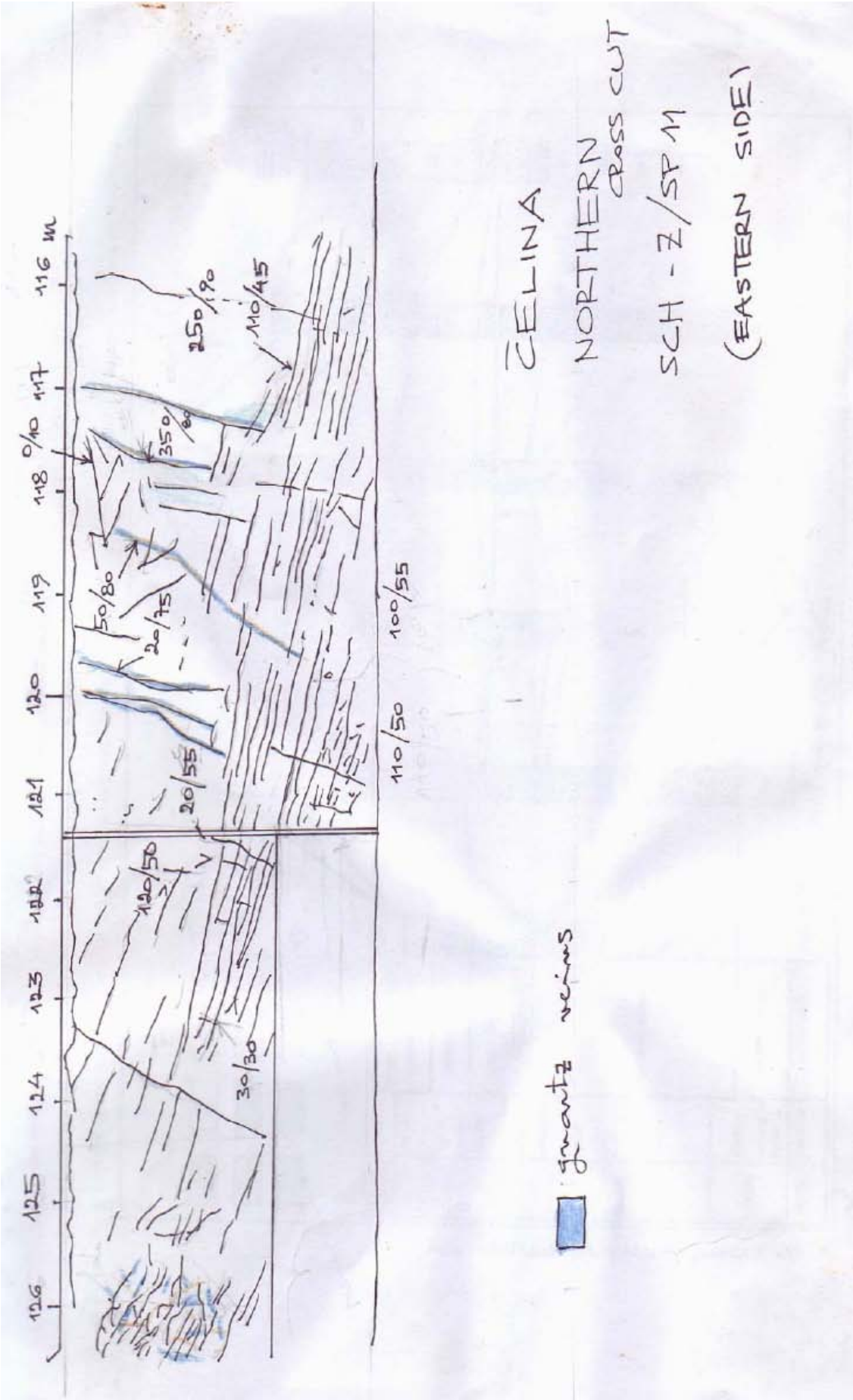
Appendix 4 Documentation of drilling locations

DRAWINGS OF SELECTED LOCATIONS

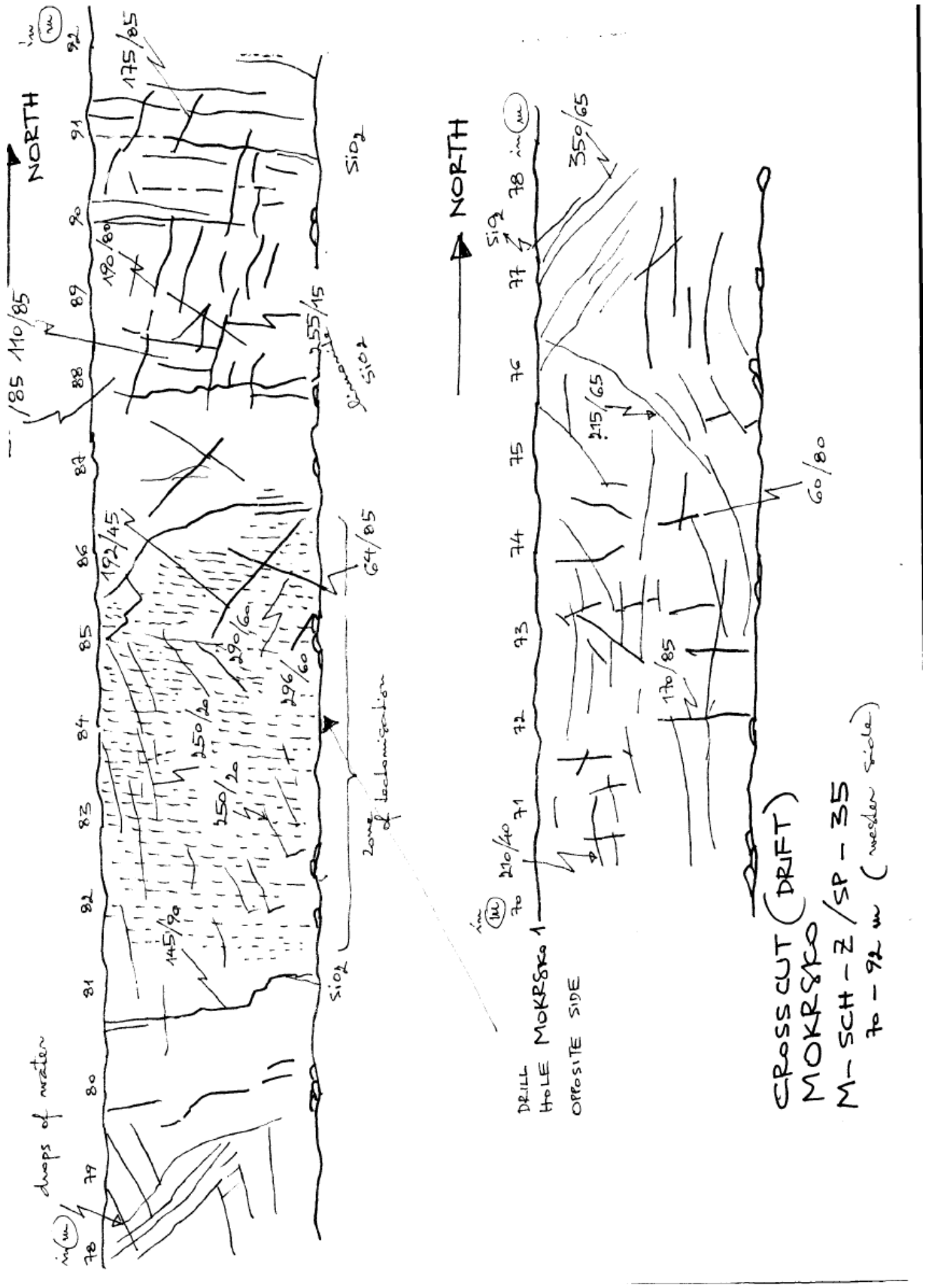
ČELINA 1



ČELINA 3


ČELINA
NORTHERN
CROSS CUT
SCH - Z/SP 11
(EASTERN SIDE)
granitz veins
116 m
117
118
119
120
121
122
123
124
125
126
0/40
250/90
110/45
350/80
50/80
20/75
20/55
120/50
30/30
110/50
100/55

MOKRSKO 1


NORTH
drops of water
SiO2
175/85
190/80
110/85
255/15
192/45
64/85
290/60
296/60
250/20
250/20
145/90
zone of tectonization
DRILL HOLE MOKRSKO 1
OPPOSITE SIDE
350/65
215/65
60/80
170/85
210/40
CROSS CUT (DRIFT)
MOKRSKO
M-SCH-Z/SP-35
70-92 m (western side)

References

MORÁVEK, P. 1996. The Mokrsko Gold Deposit. *Gold Deposits in Bohemia*, Prague: Czech Geological Survey