

S.S. N.° 685 "DELLE TRE VALLI UMBRE"
RETTIFICA DEL TRACCIATO E ADEGUAMENTO ALLA SEZ. TIPO C2
DAL km 41+500 al km 51+500
STRALCIO II - LAVORI DI ADEGUAMENTO ALLA SEZ. TIPO C2
DAL km 45+700 al km 49+300

PROGETTO DEFINITIVO

COD.

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STUDI E INDAGINI
Geologia
Relazione sui rilievi geologico strutturali di dettaglio

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APPROVATO

Relazione sui rilievi geologico strutturali di dettaglio

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1 PREMESSA

Il presente documento, quale corredo delle relazioni geologica-idrogeologica e geotecnica-sismica (cod. el. T00-GE00-GEO-RE01-A; T00-GE00-GET-RE01-A), riporta le schede di sintesi riassuntive delle attività svolte sul terreno per la ricostruzione del modello geologico e geomeccanico del sottosuolo interessato progetto della Stralcio 2 lavori di adeguamento alla sez. tipo C2 dal km 45+650 al km 49+300.

In particolare, vengono riportate le schede dei rilievi strutturali di dettaglio, eseguiti su affioramento, riportanti le descrizioni dei principali elementi geostrutturali individuati, la caratterizzazione geomeccanica delle discontinuità, le misure e gli stereogrammi relativi alle discontinuità individuate ed i valori ottenuti dalle prove sclerometriche realizzate sulle superfici di frattura.

2 SCOPO DEL DOCUMENTO ED APPROCCIO METODOLOGICO

Il presente documento si prefigge lo scopo di definire ed illustrare le caratteristiche geologiche e geologico strutturali dell'ammasso roccioso che costituisce il territorio interessato dalle opere in progetto, attraverso schede riassuntive delle attività di rilevamento effettuato.

In particolare, il lavoro in sito è stato svolto attraverso le seguenti fasi operative:

- approfondimenti conoscitivi mediante ricerca della documentazione bibliografica e degli studi pregressi;
- rilievi diretti sul terreno mirati alla definizione delle caratteristiche geologiche, geologico-strutturali degli affioramenti analizzati.

Per la definizione dell'assetto geostrutturale degli ammassi e la raccolta di altre necessarie informazioni geomeccaniche, sono stati realizzati, su affioramenti rocciosi rinvenuti nell'intorno del tracciato in progetto, 7 stazioni strutturali di dettaglio, finalizzate specificatamente alla classificazione geomeccanica degli ammassi mediante l'indice GSI - Geological Strength Index (Hoek E. & Brown E.T., 1997).

Tra le diverse attività tipiche di rilievo geostrutturale si sono previsti con sistematicità:

- rilievi delle caratteristiche di rugosità (JRC) delle fratture con profilometro (pettine di Barton);
- valutazione della dimensione dei blocchi rocciosi (ISRM, 1981; Palmstrøm, 1996, 2000), finalizzata alla classificazione geomeccanica degli ammassi mediante gli indici GSI;
- rappresentazione grafica dell'orientazione dei sistemi di discontinuità presenti mediante stereogrammi;
- determinazione GSI sia con metodo qualitativo Hoek & Marinos (2000) sia con approccio Russo (2007).

Le risultanze di dettaglio di tali rilievi geostrutturali e le relative carte di localizzazione degli stessi sono disponibili nelle "Schede di rilievo strutturale" collezionate nel capitolo seguente.

3 RILIEVI GEOSTRUTTURALI

Di seguito sono riportate le schede dei rilievi geostrutturali eseguiti.

RILIEVO GEOSTRUTTURALE

Codice rilievo:	RS_01	Coordinate UTM-WGS 84 (33T)		Quota [m s.l.m.]
Rilevatore:	Fassone A.	325665 E	4738758 N	324
Data:	18/10/22	Azimut della parete rocciosa: N350		
Comune:	Vallo di Nera	Litologia: Scaglia Rossa		
Località:	Eremita	Note:		

PLANIMETRIA DI UBICAZIONE

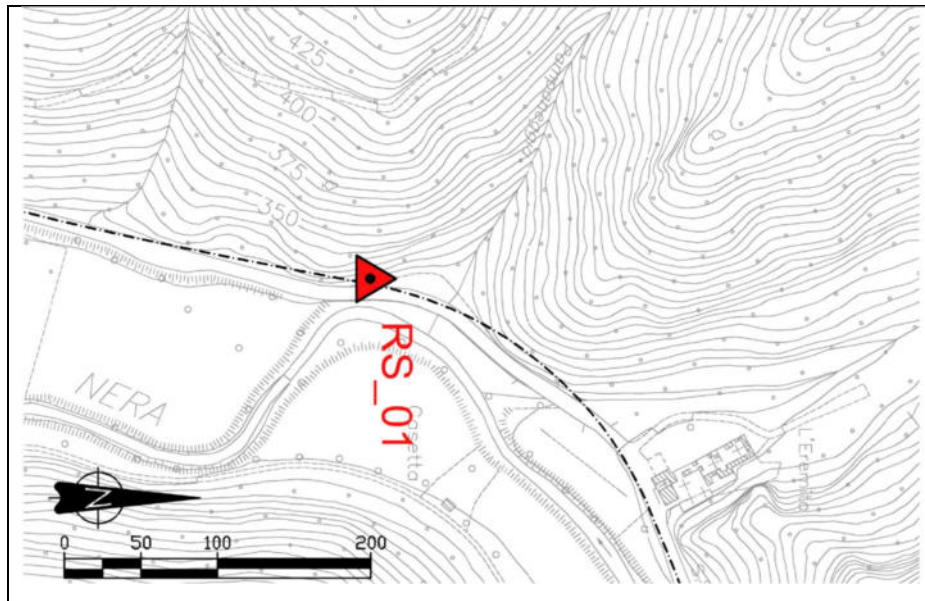


Fig.1. Carta di localizzazione del rilievo strutturale

DOCUMENTAZIONE FOTOGRAFICA

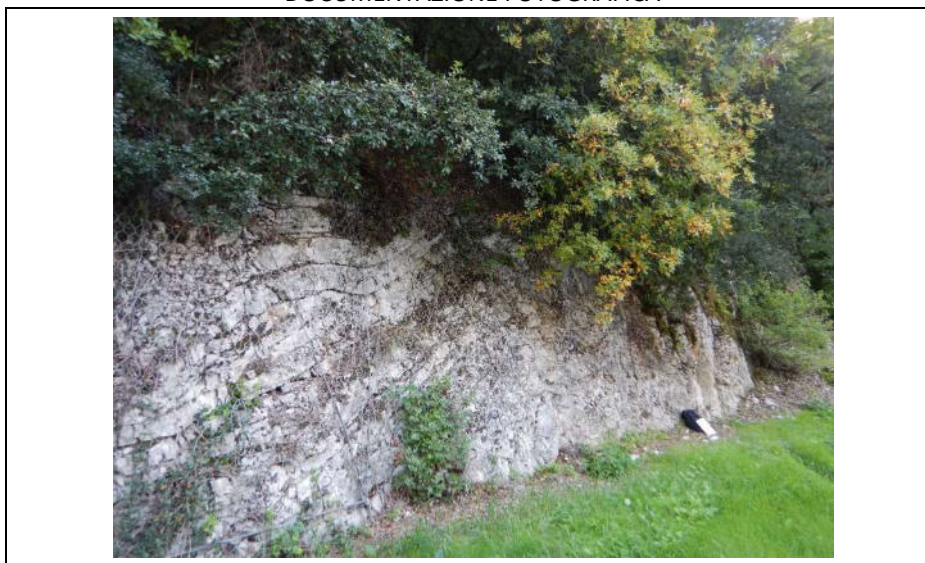


Fig.2. Vista d'insieme dell'affioramento

Relazione sui rilievi geologico strutturali di dettaglio

DESCRIZIONE DELL’AFFIORAMENTO

Affioramento roccioso: Scaglia Rossa (Turoniano inferiore - Eocene medio)
 L’ammasso si presenta fratturato e contraddistinto da fratture lungo i piani di stratificazione (St) e da quattro famiglie di discontinuità principali (F, J1, J2, J3). Le fratture, generalmente aperte sono riempite da materiale residuale.
 L’affioramento si presenta privo di emergenze idriche.

Dimensione blocchi

Minima: 8 x 5 x 4 [cm]; **Massima:** 60 x 40 x 30 [cm]; **Frequente:** 30 x 20 x 15 [cm];

Spessore roccia affiorante: 3,00 – 4,50 m

Note: Settore deformato, caratterizzato dalla presenza di strutture plicative blande, di dimensioni metriche e discontinuità tettoniche (faglia).

CARATTERISTICHE GEOMECCANICHE DELLE DISCONTINUITA’
International Society for Rock Mechanics - ISRM (1981)
BGD (Basic Geotechnical Description)

Famiglia	Orientazione		Caratteristiche delle discontinuità							
	Imm.	Incl.	Spaziatura	Persistenza	Rugosità	Grado di alterazione	Apertura	Riempimento	Condizioni Idrauliche	JRC
St	150	30	S2	P3	R4	C3 (C4)	A4 (A5)	F7	secco	8-10
F	30	65	S5	P5	R6	C3	A5	F10	secco	6-8
J1	298	70	S3 (S4)	P2	R4	C2 (C3)	A4 (A5)	F8	secco	8-10
J2	40	80	S3	P2	R4	C2 (C3)	A3	F8	secco	8-10
J3	170	20	S2 (S3)	P1	R4	C2	A2 (A1)	-	secco	8-10

Note:

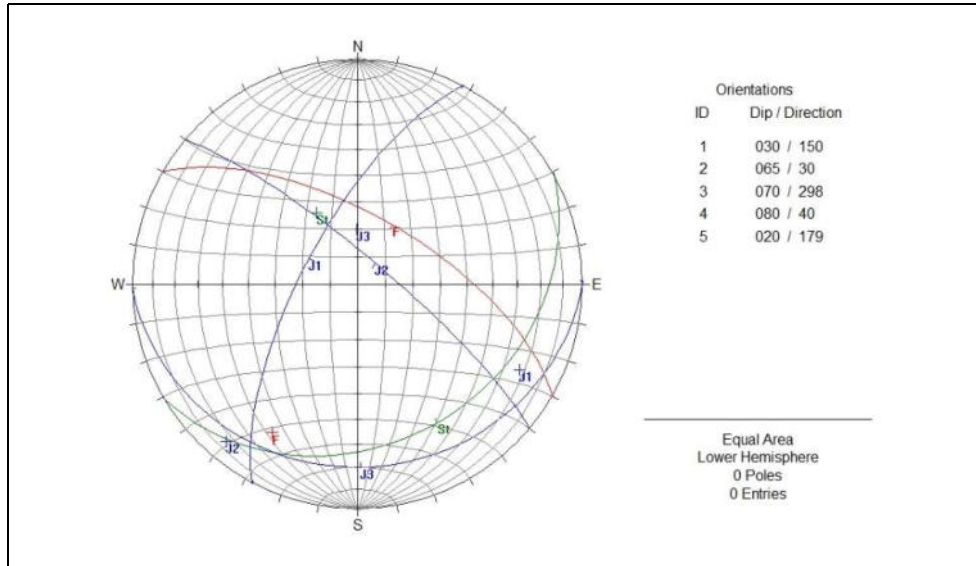
- St: Stratificazione; J: Giunto, frattura; F: Faglia, discontinuità tettonica.
- I termini tra parentesi descrivono caratteristiche subordinate.

CARATTERISTICHE GEOMECCANICHE DELLE DISCONTINUITA’
"Ratings" Evaluation – Métod PALMSTRØM (2000 – 2005)

Famiglia	Joint Condition jC (Palmstrøm) = $jR \times jL / jA$		
	jR	jL	jA
St	2	0,75	3
F	1	1	3
J1	2	2	2
J2	2	2	2
J3	2	3	2

PROIEZIONE STEREOGRAFICA DELLE DISCONTINUITA’

Relazione sui rilievi geologico strutturali di dettaglio



VOLUME DEI BLOCCHI (V_b) E FATTORE DI FORMA DEL BLOCCO (β)
Palmstrøm (2005)

Volume dei blocchi (V_b) – misurati visivamente in sito [cm ³]				Fattore di forma del blocco	
Dimensione dei blocchi	Frequente	Min	Max	Palmstrøm, 2005	Beta (β)
				Extremely lung or flat blocks	>500
L1 [cm]	30	8	60	Very long or flat blocks	100 - 500
L2 [cm]	20	5	40	Moderately long or flat blocks	50 - 100
L3 [cm]	15	4	30	Slightly long or flat blocks	32 - 50
$V_b = L1 \times L2 \times L3$	9000	160	72000	Cubical blocks	27 - 32

VALUTAZIONE DEL GSI (GEOLOGICAL STRAIN INDEX)

Hoek and Marinos P. (2000) – Determinazione GSI per rocce fratturate

Marinos V. (2007) – Determinazione GSI per rocce flyschoidi

Russo (2007) – Determinazione GSI tramite i parametri RMI: jC e Vb. *

GEOLOGICAL STRENGTH INDEX FOR JOINTED ROCKS (Hoek and Marinos, 2000)

From the lithology, structure and surface conditions of the discontinuities, estimate the average value of GSI. Do not try to be too precise. Quoting a range from 33 to 37 is more realistic than stating that GSI = 35. Note that the table does not apply to structurally controlled failures. Where weak planar structural planes are present in an unfavourable orientation with respect to the excavation face, these will dominate the rock mass behaviour. The shear strength of surfaces in rocks that are prone to deterioration as a result of changes in moisture content will be reduced if water is present. When working with rocks in the fair to very poor categories, a shift to the right may be made for wet conditions. Water pressure is dealt with by effective stress analysis.

STRUCTURE	DECREASING SURFACE QUALITY			
	VERY GOOD Very rough, fresh unweathered surfaces	GOOD Rough, slightly weathered, iron stained surfaces	FAIR Smooth, moderately weathered and altered surfaces	POOR Slickensided, highly weathered surfaces with compact coatings or fillings or angular fragments
INTACT OR MASSIVE - intact rock specimens or massive in situ rock with few widely spaced discontinuities	90			N/A
BLOCKY - well interlocked undisturbed rock mass consisting of cubical blocks formed by three intersecting discontinuity sets	80	70		
VERY BLOCKY - interlocked, partially disturbed mass with multi-faceted angular blocks formed by 4 or more joint sets		60	50	
BLOCKY/DISTURBED/SEAMY - folded with angular blocks formed by many intersecting discontinuity sets. Persistence of bedding planes or schistosity			40	
DISINTEGRATED - poorly interlocked, heavily broken rock mass with mixture of angular and rounded rock pieces			30	
LAMINATED/SHEARED - Lack of blockiness due to close spacing of weak schistosity or shear planes	N/A	N/A		20
				10

DECREASING INTERLOCKING OF ROCK PIECES

DECREASING SURFACE QUALITY

VERY GOOD
Very rough, fresh unweathered surfaces

GOOD
Rough, slightly weathered, iron stained surfaces

FAIR
Smooth, moderately weathered and altered surfaces

POOR
Slickensided, highly weathered surfaces with compact coatings or fillings or angular fragments

VERY POOR
Slickensided, highly weathered surfaces with soft clay coatings or fillings

GSI: 35 - 40

Determinazione del GSI (Hoek and Marinos P., 2000)

GEOLOGICAL STRENGTH INDEX (GSI) FOR HETEROGENEOUS ROCK MASSES SUCH AS FLYSCH (V. Marinos, 2007)

Heterogeneous rockmasses are meant those with alternating layers of clearly different lithology types with significant differences in their strength properties. For flysch, a typical formation with heterogeneous rock masses, these alternations are consisting of sandstones and siltstones. Clay shales may be present. From a description of the lithology, structure and surface conditions of discontinuities (particularly of the bedding planes), choose a box in the chart. The selection of the structure should be based on the tectonic disturbance (undisturbed, slightly disturbed, strongly disturbed - folded, desintegrated, sheared), the proportion of siltstones against sandstones and the expressed or not stratification inside the siltstone layers. In the type IV and V when the thickness of sandstone beds exceed 50cm an increase of the GSI value by 5 is suggested. From type IV and the following types, the stratification planes are perceptible inside the siltstone mass. Locate the position in the box that corresponds to the conditions and estimate the average value GSI from the contours. The determination of the structure and the condition of discontinuities may range between two adjacent fields. Note that the Hoek - Brown criterion does not apply to structurally controlled failures. Where unfavourably oriented continuous weak planar discontinuities are present, these will dominate the behaviour of the rock mass. The strength of some rock masses is reduced by the presence of groundwater and this can be allowed for by a slight shift to the right in the columns for fair, poor and very poor conditions. Water pressure does not change the value of GSI and it is dealt with by using effective stress analysis.

STRUCTURE AND COMPOSITION	DECREASE OF THE QUALITY OF DISCONTINUITIES			
	VERY GOOD Very rough, fresh unweathered surfaces	GOOD Rough, slightly weathered or oxidised surfaces	FAIR Smooth, moderately weathered and altered surfaces	POOR Very smooth, occasionally slickensided surfaces with compact coatings or fillings with angular fragments
TYPE I. Undisturbed, with thick to medium thickness sandstone beds with sporadic thin films of siltstone. In shallow tunnels or slopes where confinement is poor the mode of the failure has a kinematic character controlled by the bedding planes and GSI is meaningless	80	I	II	N/A
TYPE II. Undisturbed massive siltstone (stratification planes are imperceptible) with sporadic thin interlayers of sandstones				N/A
TYPE III. Moderately disturbed sandstones with thin films of interlayers of siltstone	60	III	IV	N/A
TYPE IV. Moderately disturbed rockmass with sandstone and siltstone similar amounts				
TYPE V. Moderately disturbed siltstones with sandstone interlayers				
TYPE VI. Moderately disturbed siltstones with sparse sandstone interlayers				
TYPE VII. Strongly disturbed, folded rockmass that retains its structure, with sandstone and siltstone in similar extend	N/A		VII	VIII
TYPE VIII. Strongly disturbed, folded rockmass, with siltstones and sandstone interlayers. The structure is retained and deformation - shearing is not strong				
TYPE IX. Desintegrated rockmass that can be found in wide zones of faults or/and of high weathering. In this type mainly brittle material is present with some disturbed siltstones between rock pieces	N/A		IX	X
TYPE X. Tectonically deformed intensively folded/ faulted siltstone or clay shale with broken and deformed sandstone layers forming an almost chaotic structure				
TYPE XI. Tectonically strongly sheared siltstone or clayey shale forming a chaotic structure with pockets of clay. Thin layers of sandstone are transformed into small rock pieces. Ultimately the ground behavior is that of a soil	N/A	N/A		XI

DECREASE OF THE QUALITY OF DISCONTINUITIES

VERY GOOD
Very rough, fresh unweathered surfaces

GOOD
Rough, slightly weathered or oxidised surfaces

FAIR
Smooth, moderately weathered and altered surfaces

POOR
Very smooth, occasionally slickensided surfaces with compact coatings or fillings with angular fragments

VERY POOR
Very smooth, slickensided or highly weathered surfaces with soft clay coating or fillings

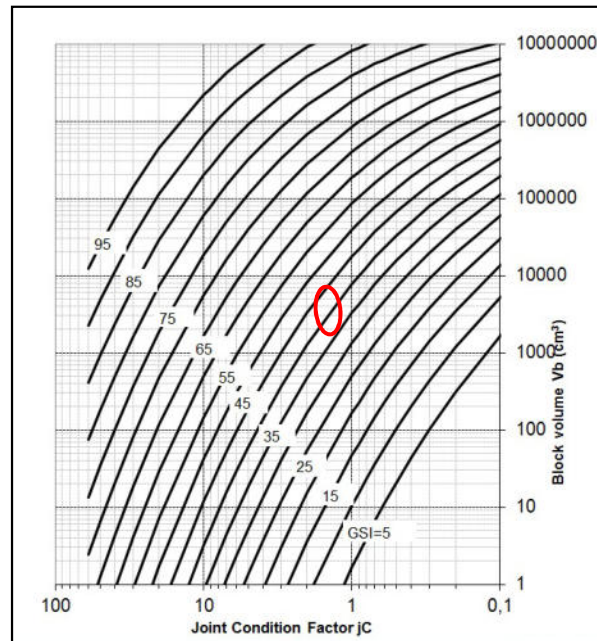
N/A Means geologically impossible combination. In the non - shadowed areas, such rockmasses are not impossible to find but it is very unusual

Direction of tectonic disturbance and deformation of equivalent rockmass lithology

GSI: xxx

Determinazione del GSI (Marinos V., 2007)

Relazione sui rilievi geologico strutturali di dettaglio



GSI: 35-45

Determinazione del GSI tramite i parametri RMi: jC e Vb. (Russo, 2007)

*RMi: Rock Mass index (Palmstrøm, 1994)

VALUTAZIONE DELLA RESISTENZA A COMPRESSIONE UNIASSIALE MEDIANTE SCLEROMETRO (Martello di Schmidt)
ISRM (1978a e 1978b); Miller (1965)

Famiglia	Direzione di applicazione	Indice di rimbalzo (Martello di Schmidt)											
		1	2	3	4	5	6	7	8	9	10	11	12
J1		44	38	44	40	48	46	44	53	52	48	44	45
J2		46	44	28	25	40	36	20	22	38	28	15	22
J3		16	16	18	20	34	16	16	16	32	24	20	16

APPENDICE

1_Caratteristiche geomeccaniche delle discontinuità Basic Geotechnical Description (ISRM, 1981)

Characteristics	Id	Typology	Range	
SPACING	S1	Very close spacing	< 6 cm	
	S2	Close spacing	6-20 cm	
	S3	Moderate spacing	20 - 60 cm	
	S4	Wide spacing	60 - 200 cm	
	S5	Very wide spacing	> 200 cm	
PERSISTENCE	P1	Very low persistence	< 1 m	
	P2	Low persistence	1 – 3 m	
	P3	Medium persistence	10 – 20 m	
	P4	High persistence	10 – 20 m	
	P5	Very high persistence	> 20m	
ROUGHNESS	Stepped	R1	Rough (or irregular)	-
		R2	Smooth	-
		R3	Slickenside	-
	Undulating	R4	Rough (or irregular)	-
		R5	Smooth	-
		R6	Slickenside	-
	Planar	R7	Rough (or irregular)	-
		R8	Smooth	-
		R9	Slickenside	-
JOINT CONDITIONS	C1	Fresh	-	
	C2	Slightly weathered	-	
	C3	Moderately weathered	-	
	C4	Highly weathered	-	
	C5	Completely weathered	-	
	C6	Residual soil	-	
APERTURE	A1	Closed	0.0 mm	
	A2	Very tight - Tight	< 0.1 mm	
	A3	Partly open - Open	0.1 mm – 1 mm	
	A4	Open - Moderately wide	1 mm – 5 mm	
	A5	Moderately wide - Wide	> 5mm	

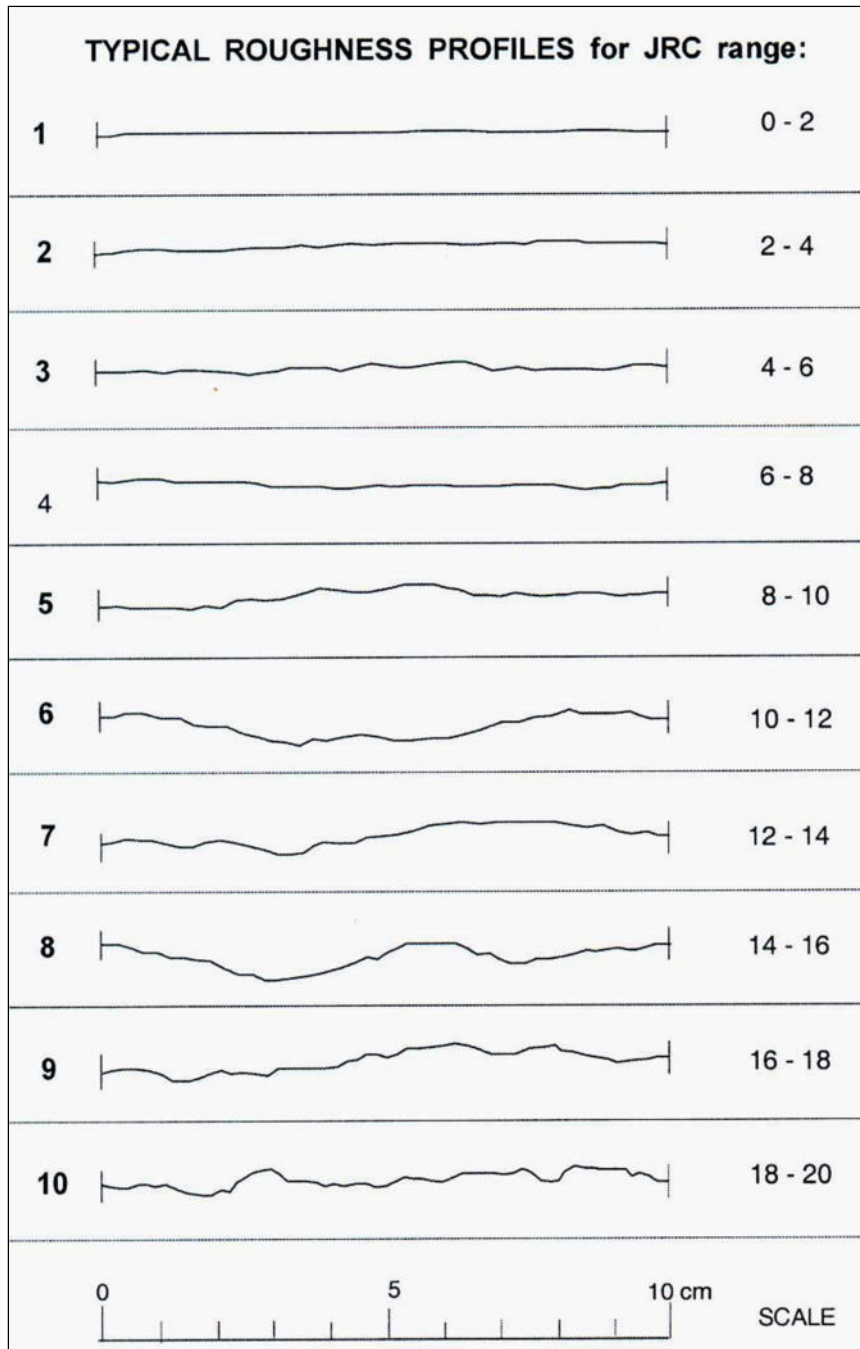
2_Caratteristiche geomeccaniche delle discontinuità

"Ratings" Evaluation – Métod PALMSTRØM (2000 – 2005)

"RATINGS" EVALUATION – MÉTODO PALMSTRØM (2000 - 2005)						
Joint Condition Factor j_C		$j_C \text{ (Palmstrøm)} = j_R \times j_L / j_A$				
Joint roughness factor (j_R)		Large scale waviness of joint plane				
		Planar	Slightly undulating	Undulating	Strongly undulating	Stepped or Interlocking
small scale smoothness of joint surface	Very rough	2	3	4	6	6
	Rough	1,5	2	3	4,5	6
	Smooth	1	1,5	2	3	4
	Polished or slickenside *	0,5	1	1,5	2	3
For filled joint $j_R=1$. For irregular joint a rating of $j_R=5$ is suggested						
*) for slickenside surfaces the rating apply to possible movement along the lineations.						
Joint alteration factor (j_A)						
Contact between joint walls	Joint wall character		Condition		Wall contact	
	CLEAN JOINTS	Healed or welded joints	filling of quartz, epidote, etc.		0,75	
		Fresh joint walls	no coating or filling, except from staining (rust)		1	
		Altered joint walls	one grade higher alteration than the rock		2	
	two grades higher alteration than the rock		4			
	COATING or THIN FILLING	Friction materials	sand, silt calcite, etc. without content of clay		3	
Cohesive materials		clay, chlorite, talc, etc.		4		
Partly or no wall contact	Filling	Type	Party wall contact	No wall contact		
			thin filling (<5mm)	thick filling or gouge		
	Friction materials	sand, silt calcite, etc. (non softening)	4	8		
	Hard, cohesive materials	compacted filling of clay, chlorite, talc, etc.	6	6-10		
	Soft, cohesive materials	medium to low ever consolidated clay, chlorite, talc, etc.	8	12		
Swelling clay materials	filling material exhibits swelling properties	8-12	13-20			
Joint size factor (j_L)						
Type	Length	Size	Continuous joints	Discontin. Joints *		
Bedding or foliation partings	<0,5 m	Very short	3	6		
	0,1-1 m	short or small	2	4		
		medium	1	2		
		long or large	0,75	1,5		
(Filled) joint, seam or shear **	>30 m	very long or large	0,50	1		
*) Discontinuous joints end in massive rock			**) Often a singularity and should in these cases be treated separately			

3_Profili tipici di scabrezza (rugosità)

Barton & Choubey, 1977



RILIEVO GEOSTRUTTURALE

Codice rilievo:	RS_02	Coordinate UTM-WGS 84 (33T)		Quota [m s.l.m.]
Rilevatore:	Fassone A.	325827E	4738959N	345
Data:	18/10/22	Azimut della parete rocciosa: N110		
Comune:	Vallo di Nera	Litologia: Scaglia Rossa		
Località:	Eremita Cimitero	Note:		

PLANIMETRIA DI UBICAZIONE

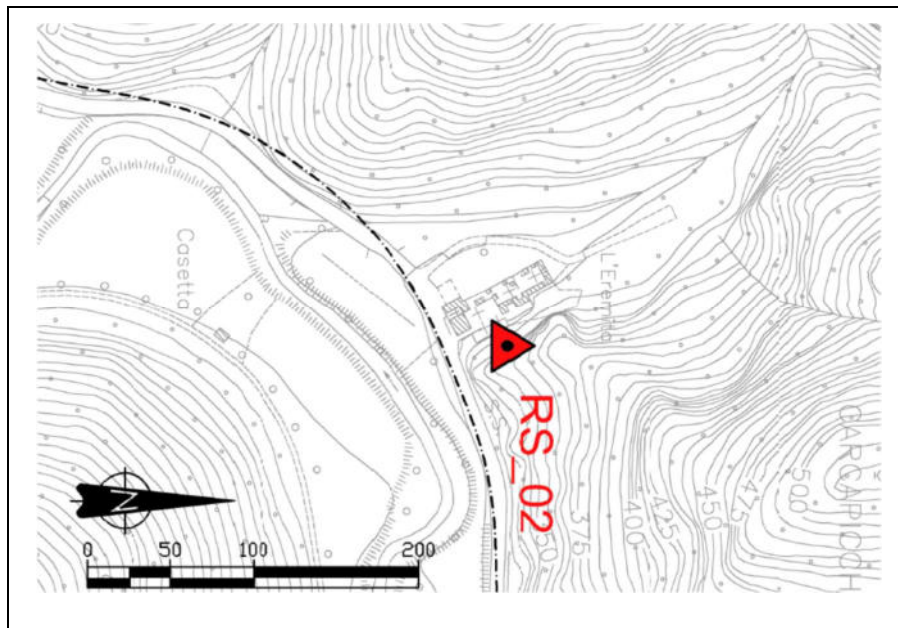


Fig.1. Carta di localizzazione del rilievo strutturale

DOCUMENTAZIONE FOTOGRAFICA

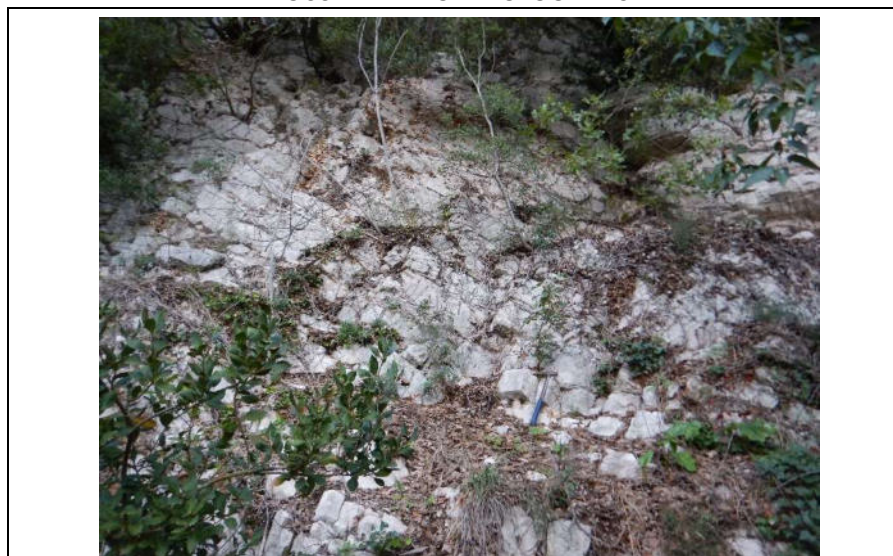


Fig.2. Vista d'insieme dell'affioramento

DESCRIZIONE DELL’AFFIORAMENTO

Affioramento roccioso: Scaglia Rossa (Turoniano inferiore - Eocene medio).
L’ammasso presenta stratificazione (St) persistente e risulta fratturato da due famiglie di discontinuità principali (Jn, J2).
Le fratture, parzialmente aperte sono riempite da materiale residuale, con superfici moderatamente alterate.
L’affioramento si presenta privo di emergenze idriche.

Dimensione blocchi

Minima: 15x10x8 [cm]; **Massima:** 60x50x35 [cm]; **Frequente:** 20x40x35 [cm];

Spessore roccia affiorante: 10 – 20 m.

Note:

CARATTERISTICHE GEOMECCANICHE DELLE DISCONTINUITA’
International Society for Rock Mechanics - ISRM (1981)
BGD (Basic Geotechnical Description)

Famiglia	Orientazione		Caratteristiche delle discontinuità							
	Imm.	Incl.	Spaziatura	Persistenza	Rugosità	Grado di alterazione	Apertura	Riempimento	Condizioni Idrauliche	JRC
St	110	44	S2 (S3)	P4	R4	C3	A3 (A4)	F9	secco	8-10
J1	310	64	S2	P1	R4	C3	A4 (A5)	-	secco	8-10
J2	40	88	S3	P2	R4	C3	A5 (A4)	F8	Secco	8-10

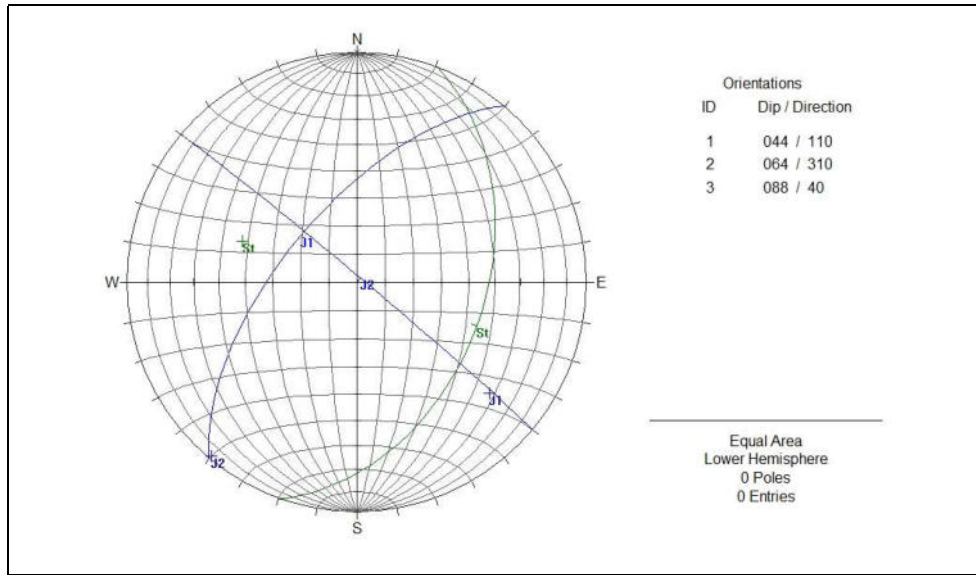
Note:

- St: Stratificazione; J: Giunto, frattura; F: Faglia, discontinuità tettonica.
- I termini tra parentesi descrivono caratteristiche subordinate.

CARATTERISTICHE GEOMECCANICHE DELLE DISCONTINUITA’
“Ratings” Evaluation – Métod PALMSTRØM (2000 – 2005)

Famiglia	Joint Condition jC (Palmstrøm) = $jR \times jL / jA$		
	jR	jL	JA
St	2	1	2
J1	3	2	3
J2	2	2	2

PROIEZIONE STEREOGRAFICA DELLE DISCONTINUITA'



VOLUME DEI BLOCCHI (V_b) E FATTORE DI FORMA DEL BLOCCO (β)
Palmstrøm (2005)

Volume dei blocchi (V_b) – misurati visivamente in sito [cm ³]				Fattore di forma del blocco	
Dimensione dei blocchi	Frequente	Min	Max	Palmstrøm, 2005	Beta (β)
				Extremely lung or flat blocks	>500
L1 [cm]	20	8	60	Very long or flat blocks	100 - 500
L2 [cm]	40	10	50	Moderately long or flat blocks	50 - 100
L3 [cm]	35	15	35	Slightly long or flat blocks	32 - 50
$V_b = L1 \times L2 \times L3$	28000	1200	105000	Cubical blocks	27 - 32

VALUTAZIONE DEL GSI (GEOLOGICAL STRAIN INDEX)

Hoek and Marinos P. (2000) – Determinazione GSI per rocce fratturate

Marinos V. (2007) – Determinazione GSI per rocce flyschoidi

Russo (2007) – Determinazione GSI tramite i parametri RMI: jC e Vb. *

GEOLOGICAL STRENGTH INDEX FOR JOINTED ROCKS (Hoek and Marinos, 2000)

From the lithology, structure and surface conditions of the discontinuities, estimate the average value of GSI. Do not try to be too precise. Quoting a range from 33 to 37 is more realistic than stating that GSI = 35. Note that the table does not apply to structurally controlled failures. Where weak planar structural planes are present in an unfavourable orientation with respect to the excavation face, these will dominate the rock mass behaviour. The shear strength of surfaces in rocks that are prone to deterioration as a result of changes in moisture content will be reduced if water is present. When working with rocks in the fair to very poor categories, a shift to the right may be made for wet conditions. Water pressure is dealt with by effective stress analysis.

STRUCTURE	SURFACE CONDITIONS			
	VERY GOOD Very rough, fresh unweathered surfaces	GOOD Rough, slightly weathered, iron stained surfaces	FAIR Smooth, moderately weathered and altered surfaces	POOR Stickensided, highly weathered surfaces with compact coatings or fillings or angular fragments
INTACT OR MASSIVE - intact rock specimens or massive in situ rock with few widely spaced discontinuities	90			N/A
BLOCKY - well interlocked undisturbed rock mass consisting of cubical blocks formed by three intersecting discontinuity sets	80	70		
VERY BLOCKY - interlocked, partially disturbed mass with multi-faceted angular blocks formed by 4 or more joint sets		60		
BLOCKY/DISTURBED/SEAMY - folded with angular blocks formed by many intersecting discontinuity sets. Persistence of bedding planes or schistosity			50	
DISINTEGRATED - poorly interlocked, heavily broken rock mass with mixture of angular and rounded rock pieces				30
LAMINATED/SHEARED - Lack of blockiness due to close spacing of weak schistosity or shear planes				20
				10

DECREASING INTERLOCKING OF ROCK PIECES

DECREASING SURFACE QUALITY

VERY GOOD
Very rough, fresh unweathered surfaces

GOOD
Rough, slightly weathered, iron stained surfaces

FAIR
Smooth, moderately weathered and altered surfaces

POOR
Stickensided, highly weathered surfaces with compact coatings or fillings or angular fragments

VERY POOR
Stickensided, highly weathered surfaces with soft clay coatings or fillings

GSI: 40-45

Determinazione del GSI (Hoek and Marinos P., 2000)

GEOLOGICAL STRENGTH INDEX (GSI) FOR HETEROGENEOUS ROCK MASSES SUCH AS FLYSCH (V. Marinos, 2007)

Heterogeneous rockmasses are meant those with alternating layers of clearly different lithology types with significant differences in their strength properties. For flysch, a typical formation with heterogeneous rock masses, these alternations are consisting of sandstones and siltstones. Clay shales may be present. From a description of the lithology, structure and surface conditions of discontinuities (particularly of the bedding planes), choose a box in the chart. The selection of the structure should be based on the tectonic disturbance (undisturbed, slightly disturbed, strongly disturbed - folded, desintegrated, sheared), the proportion of siltstones against sandstones and the expressed or not stratification inside the siltstone layers. In the type IV and V when the thickness of sandstone beds exceed 50cm an increase of the GSI value by 5 is suggested. From type IV and the following types, the stratification planes are perceptible inside the siltstone mass. Locate the position in the box that corresponds to the conditions and estimate the average value GSI from the contours. The determination of the structure and the condition of discontinuities may range between two adjacent fields. Note that the Hoek - Brown criterion does not apply to structurally controlled failures. Where unfavourably oriented continuous weak planar discontinuities are present, these will dominate the behaviour of the rock mass. The strength of some rock masses is reduced by the presence of groundwater and this can be allowed for by a slight shift to the right in the columns for fair, poor and very poor conditions. Water pressure does not change the value of GSI and it is dealt with by using effective stress analysis.

STRUCTURE AND COMPOSITION	SURFACE CONDITIONS OF DISCONTINUITIES (Predominantly bedding planes)			
	VERY GOOD Very rough, fresh unweathered surfaces	GOOD Rough, slightly weathered or oxidised surfaces	FAIR Smooth, moderately weathered and altered surfaces	POOR Very smooth, occasionally stickensided surfaces with compact coatings or fillings with angular fragments
TYPE I. Undisturbed, with thick to medium thickness sandstone beds with sporadic thin films of siltstone. In shallow tunnels or slopes where confinement is poor the mode of the failure has a kinematic character controlled by the bedding planes and GSI is meaningless	80	I	II	N/A
TYPE II. Undisturbed massive siltstone (stratification planes are imperceptible) with sporadic thin interlayers of sandstones				N/A
TYPE III. Moderately disturbed sandstones with thin films of interlayers of siltstone	60	III	IV	V
TYPE IV. Moderately disturbed rockmass with sandstone and siltstone similar amounts				N/A
TYPE V. Moderately disturbed siltstones with sandstone interlayers				N/A
TYPE VI. Moderately disturbed siltstones with sparse sandstone interlayers				N/A
TYPE VII. Strongly disturbed, folded rockmass that retains its structure, with sandstone and siltstone in similar extend	N/A		VII	VIII
TYPE VIII. Strongly disturbed, folded rockmass, with siltstones and sandstone interlayers. The structure is retained and deformation - shearing is not strong				
TYPE IX. Desintegrated rockmass that can be found in wide zones of faults or/and of high weathering. In this type mainly brittle material is present with some disturbed siltstones between rock pieces	N/A		IX	X
TYPE X. Tectonically deformed intensively folded/ faulted siltstone or clay shale with broken and deformed sandstone layers forming an almost chaotic structure				
TYPE XI. Tectonically strongly sheared siltstone or clayey shale forming a chaotic structure with pockets of clay. Thin layers of sandstone are transformed into small rock pieces. Ultimately the ground behavior is that of a soil	N/A	N/A		XI

DECREASE OF THE QUALITY OF DISCONTINUITIES

VERY GOOD
Very rough, fresh unweathered surfaces

GOOD
Rough, slightly weathered or oxidised surfaces

FAIR
Smooth, moderately weathered and altered surfaces

POOR
Very smooth, occasionally stickensided surfaces with compact coatings or fillings with angular fragments

VERY POOR
Very smooth, stickensided or highly weathered surfaces with soft clay coating or fillings

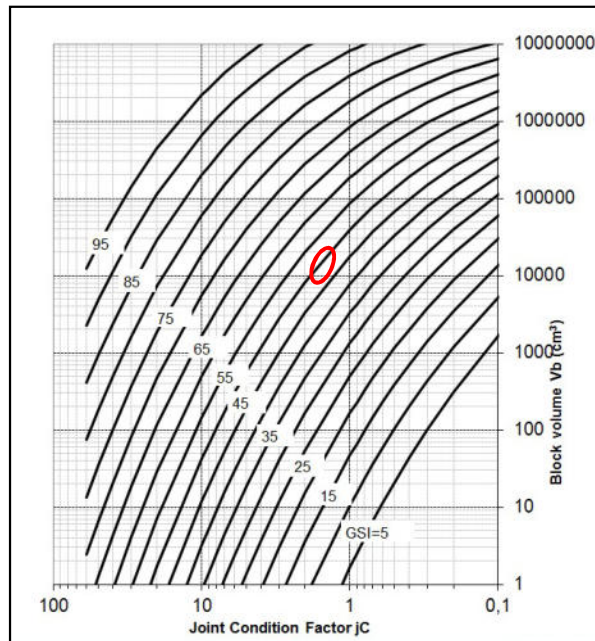
N/A Means geologically impossible combination. In the non - shadowed areas, such rockmasses are not impossible to find but it is very unusual

→ Direction of tectonic disturbance and deformation of equivalent rockmass lithology

GSI: xxx

Determinazione del GSI (Marinos V., 2007)

Relazione sui rilievi geologico strutturali di dettaglio



GSI: 45 -50

Determinazione del GSI tramite i parametri RMI: jC e Vb. (Russo, 2007)

*RMI: Rock Mass index (Palmstrøm, 1994)

VALUTAZIONE DELLA RESISTENZA A COMPRESIONE UNIASSIALE MEDIANTE SCLEROMETRO (Martello di Schmidt)
ISRM (1978a e 1978b); Miller (1965)

Famiglia	Direzione di applicazione	Indice di rimbalzo (Martello di Schmidt)											
		1	2	3	4	5	6	7	8	9	10	11	12
J1		28	26	30	40	48	50	50	45	26	42	38	34
J2		21	40	30	40	30	30	26	28	36	34	42	38
J3		47	46	46	34	47	34	32	50	44	40	32	38

APPENDICE

1_Caratteristiche geomeccaniche delle discontinuità Basic Geotechnical Description (ISRM, 1981)

Characteristics	Id	Typology	Range	
SPACING	S1	Very close spacing	< 6 cm	
	S2	Close spacing	6-20 cm	
	S3	Moderate spacing	20 - 60 cm	
	S4	Wide spacing	60 - 200 cm	
	S5	Very wide spacing	> 200 cm	
PERSISTENCE	P1	Very low persistence	< 1 m	
	P2	Low persistence	1 – 3 m	
	P3	Medium persistence	10 – 20 m	
	P4	High persistence	10 – 20 m	
	P5	Very high persistence	> 20m	
ROUGHNESS	Stepped	R1	Rough (or irregular)	-
		R2	Smooth	-
		R3	Slickenside	-
	Undulating	R4	Rough (or irregular)	-
		R5	Smooth	-
		R6	Slickenside	-
	Planar	R7	Rough (or irregular)	-
		R8	Smooth	-
		R9	Slickenside	-
JOINT CONDITIONS	C1	Fresh	-	
	C2	Slightly weathered	-	
	C3	Moderately weathered	-	
	C4	Highly weathered	-	
	C5	Completely weathered	-	
	C6	Residual soil	-	
APERTURE	A1	Closed	0.0 mm	
	A2	Very tight - Tight	< 0.1 mm	
	A3	Partly open - Open	0.1 mm – 1 mm	
	A4	Open - Moderately wide	1 mm – 5 mm	
	A5	Moderately wide - Wide	> 5mm	

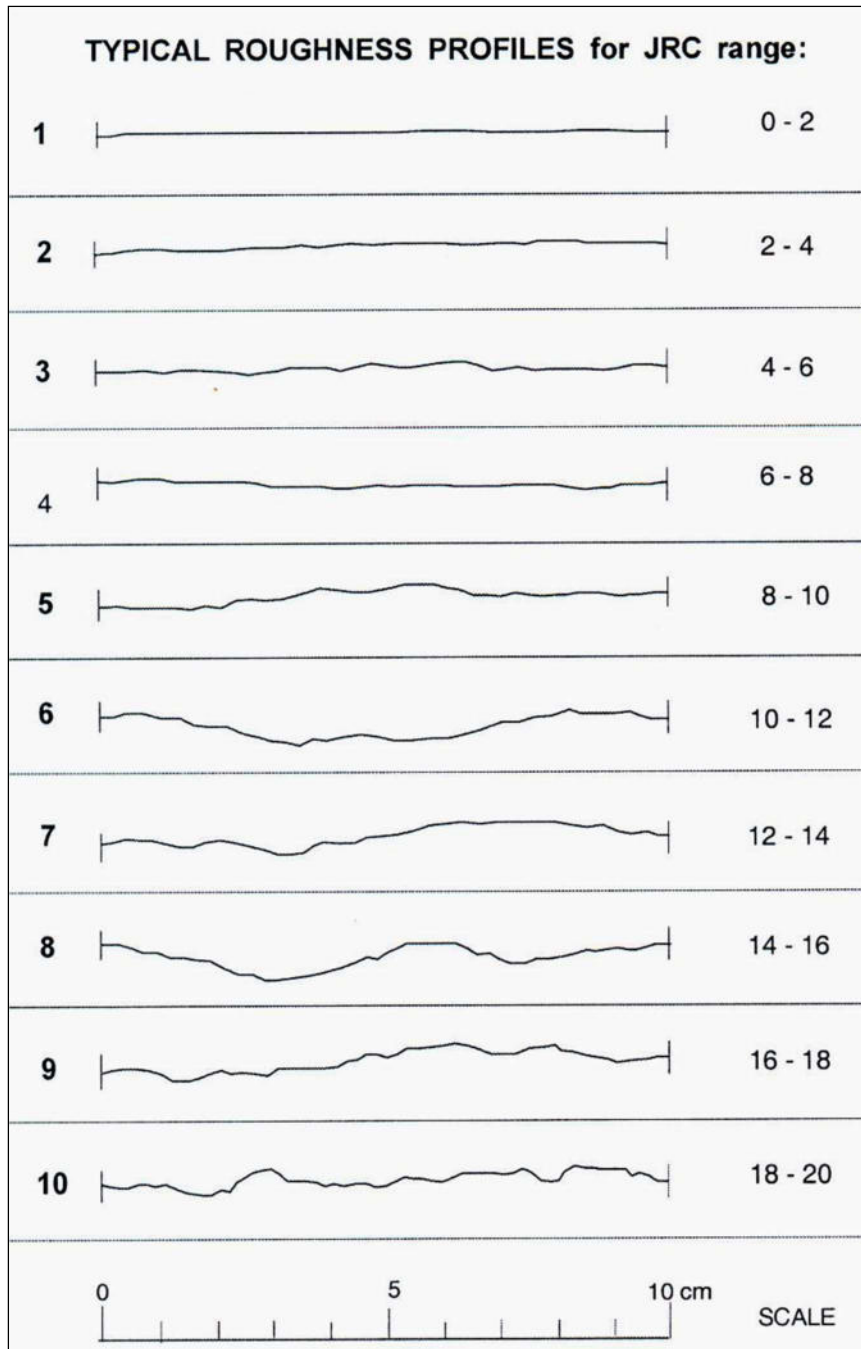
2_Caratteristiche geomeccaniche delle discontinuità

"Ratings" Evaluation – Métod PALMSTRØM (2000 – 2005)

"RATINGS" EVALUATION – MÉTODO PALMSTRØM (2000 - 2005)						
Joint Condition Factor j_C		j_C (Palmstrøm) = $j_R \times j_L / j_A$				
Joint roughness factor (j_R)		Large scale waviness of joint plane				
		Planar	Slightly undulating	Undulating	Strongly undulating	Stepped or Interlocking
small scale smoothness of joint surface	Very rough	2	3	4	6	6
	Rough	1,5	2	3	4,5	6
	Smooth	1	1,5	2	3	4
	Polished or slickenside *	0,5	1	1,5	2	3
<i>For filled joint $j_R=1$. For irregular joint a rating of $j_R=5$ is suggested</i>						
<i>*) for slickenside surfaces the rating apply to possible movement along the <u>lineations</u>.</i>						
Joint alteration factor (j_A)						
Contact between joint walls	Joint wall character		Condition		Wall contact	
	CLEAN JOINTS	Healed or welded joints	filling of quartz, epidote, etc.		0,75	
		Fresh joint walls	no coating or filling, except from staining (rust)		1	
		Altered joint walls	one grade higher alteration than the rock		2	
	two grades higher alteration than the rock		4			
	COATING or THIN FILLING	Friction materials	sand, silt calcite, etc. without content of clay		3	
Cohesive materials		clay, chlorite, talc, etc.		4		
Partly or no wall contact	Filling	Type		Party wall contact	No wall contact	
				thin filling (<5mm)	thick filling or gouge	
	Friction materials	sand, silt calcite, etc. (<u>non softening</u>)		4	8	
	Hard, cohesive materials	compacted filling of clay, chlorite, talc, etc.		6	6-10	
	Soft, cohesive materials	medium to low ever consolidated clay, chlorite, talc, etc.		8	12	
Swelling clay materials	filling material exhibits swelling properties		8-12	13-20		
Joint size factor (j_L)						
Type	Length	Size		Continuous joints	Discontin. Joints *	
Bedding or foliation partings	<0,5 m	Very short		3	6	
	Joints	0,1-1 m	short or small		2	4
		1-10 m	medium		1	2
	10-30 m	long or large		0,75	1,5	
(Filled) joint, seam or shear **	>30 m	very long or large		0,50	1	
<i>*) Discontinuous joints end in massive rock</i>				<i>***) Often a singularity and should in these cases be treated separately</i>		

3_Profilo tipici di scabrezza (rugosità)

Barton & Choubey, 1977



RILIEVO GEOSTRUTTURALE

Codice rilievo:	RS_03	Coordinate UTM-WGS 84 (33T)		Quota [m s.l.m.]
Rilevatore:	Fassone A.	326092 E	4739178 N	328
Data:	19/10/22	Azimut della parete rocciosa: N15		
Comune:	Vallo di Nera	Litologia: Scaglia Rossa		
Località:	Eremita	Note: Affioramento lungo strada, in prossimità della galleria paramassi esistente		

PLANIMETRIA DI UBICAZIONE



Fig.1. Carta di localizzazione del rilievo strutturale

DOCUMENTAZIONE FOTOGRAFICA

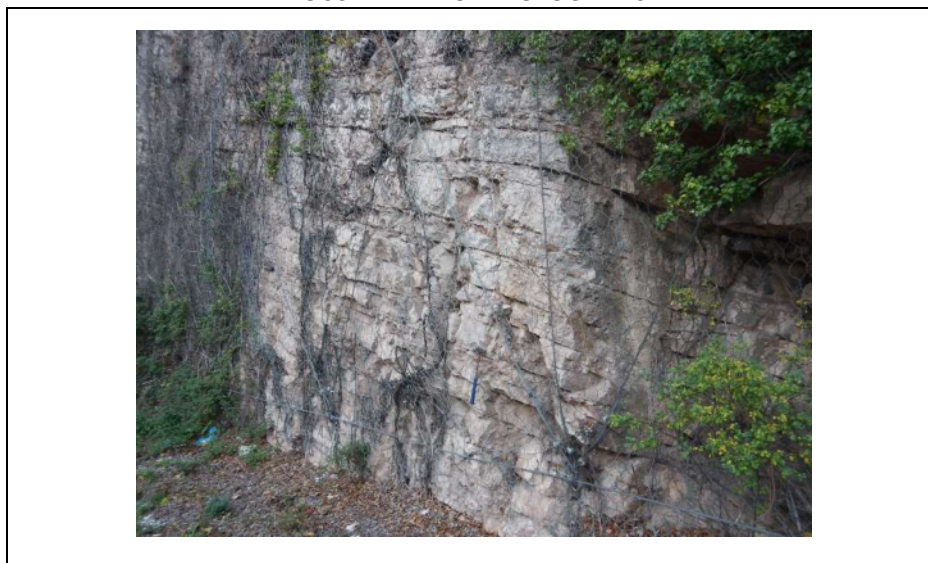


Fig.2. Vista d'insieme dell'affioramento

DESCRIZIONE DELL’AFFIORAMENTO

Affioramento roccioso: Scaglia Rossa (Turoniano inferiore - Eocene medio)
L’ammasso si presenta fratturato e contraddistinto da fratture lungo i piani di stratificazione (St) e da due famiglie di discontinuità principali (J1, J2). Le fratture, generalmente aperte, con superfici moderatamente alterate, sono riempite da materiale residuale. L’affioramento si presenta privo di emergenze idriche.

Dimensione blocchi

Minima: 5 x 4 x 6 [cm]; **Massima:** 65 x 45 x 30 [cm]; **Frequente:** 20 x 10 x 15 [cm];

Spessore roccia affiorante: 10 – 15m

Note: Settore deformato, caratterizzato dalla presenza di strutture plicative blande aventi dimensioni metriche

CARATTERISTICHE GEOMECCANICHE DELLE DISCONTINUITA’
International Society for Rock Mechanics - ISRM (1981)
BGD (Basic Geotechnical Description)

Famiglia	Orientazione		Caratteristiche delle discontinuità							
	Imm.	Incl.	Spaziatura	Persistenza	Rugosità	Grado di alterazione	Apertura	Riempimento	Condizioni Idrauliche	JRC
St	320	20	S2 (S3)	P4	R4	C3	A3 (A4)	F6 (F7)	Secco	8-10
J1	270	90	S2 (S3)	P3	R4	C3	A4 (A5)	F7	Secco	8-10
J2	310	52	S2 (S3)	P2	R4	C2 (C3)	A3(A4)	-	Secco	8-10

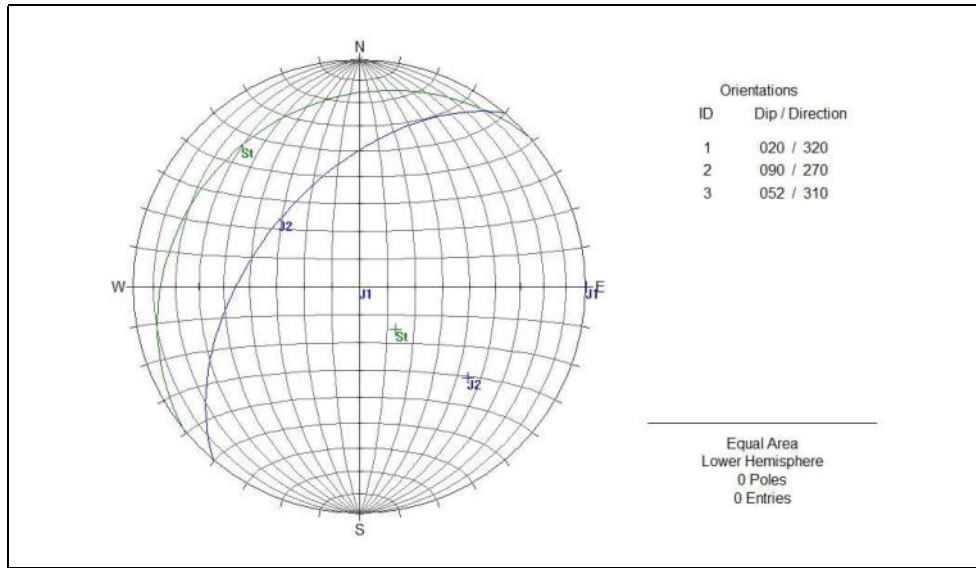
Note:

- St: Stratificazione; J: Giunto, frattura; F: Faglia, discontinuità tettonica.
- I termini tra parentesi descrivono caratteristiche subordinate.

CARATTERISTICHE GEOMECCANICHE DELLE DISCONTINUITA’
"Ratings" Evaluation – Metod PALMSTRØM (2000 – 2005)

Famiglia	Joint Condition jC (Palmstrøm) = jR x jL /jA		
	jR	jL	JA
St	2	1	3
J1	3	2	3
J2	2	2	2

PROIEZIONE STEREOGRAFICA DELLE DISCONTINUITA'



VOLUME DEI BLOCCHI (V_b) E FATTORE DI FORMA DEL BLOCCO (β)
Palmstrøm (2005)

Volume dei blocchi (V_b) – misurati visivamente in sito [cm ³]				Fattore di forma del blocco	
Dimensione dei blocchi	Frequente	Min	Max	Palmstrøm, 2005	
				Extremely lung or flat blocks	Beta (β)
L1 [cm]	25	5	65	Very long or flat blocks	100 - 500
L2 [cm]	10	4	30	Moderately long or flat blocks	50 - 100
L3 [cm]	15	6	45	Slightly long or flat blocks	32 - 50
$V_b = L1 \times L2 \times L3$	3750	120	87750	Cubical blocks	27 - 32

VALUTAZIONE DEL GSI (GEOLOGICAL STRAIN INDEX)

Hoek and Marinos P. (2000) – Determinazione GSI per rocce fratturate

Marinos V. (2007) – Determinazione GSI per rocce flyschoidi

Russo (2007) – Determinazione GSI tramite i parametri RMI: jC e Vb. *

GEOLOGICAL STRENGTH INDEX FOR JOINTED ROCKS (Hoek and Marinos, 2000)		SURFACE CONDITIONS	
<p>From the lithology, structure and surface conditions of the discontinuities, estimate the average value of GSI. Do not try to be too precise. Quoting a range from 33 to 37 is more realistic than stating that GSI = 35. Note that the table does not apply to structurally controlled failures. Where weak planar structural planes are present in an unfavourable orientation with respect to the excavation face, these will dominate the rock mass behaviour. The shear strength of surfaces in rocks that are prone to deterioration as a result of changes in moisture content will be reduced if water is present. When working with rocks in the fair to very poor categories, a shift to the right may be made for wet conditions. Water pressure is dealt with by effective stress analysis.</p>		VERY GOOD Very rough, fresh unweathered surfaces	VERY POOR Slickensided, highly weathered surfaces with soft clay coatings or fillings
		GOOD Rough, slightly weathered, iron stained surfaces	VERY POOR Slickensided, highly weathered surfaces with compact coatings or fillings or angular fragments
STRUCTURE		DECREASING SURFACE QUALITY →	
INTACT OR MASSIVE - intact rock specimens or massive in situ rock with few widely spaced discontinuities	90	N/A	N/A
BLOCKY - well interlocked undisturbed rock mass consisting of cubical blocks formed by three intersecting discontinuity sets	80		
VERY BLOCKY - interlocked, partially disturbed mass with multi-faceted angular blocks formed by 4 or more joint sets	70		
BLOCKY/DISTURBED/SEAMY - folded with angular blocks formed by many intersecting discontinuity sets. Persistence of bedding planes or schistosity	60		
DISINTEGRATED - poorly interlocked, heavily broken rock mass with mixture of angular and rounded rock pieces	50		
LAMINATED/SHEARED - Lack of blockiness due to close spacing of weak schistosity or shear planes	40		
	30		
	20		
	10		

GSI: 35 - 40

Determinazione del GSI (Hoek and Marinos P., 2000)

GEOLOGICAL STRENGTH INDEX (GSI) FOR HETEROGENEOUS ROCK MASSES SUCH AS FLYSCH (V. Marinos, 2007)		SURFACE CONDITIONS OF DISCONTINUITIES (Predominantly bedding planes)	
<p>Heterogeneous rockmasses are meant those with alternating layers of clearly different lithology types with significant differences in their strength properties. For flysch, a typical formation with heterogeneous rock masses, these alternations are consisting of sandstones and siltstones. Clay shales may be present. From a description of the lithology, structure and surface conditions of discontinuities (particularly of the bedding planes), choose a box in the chart. The selection of the structure should be based on the tectonic disturbance (undisturbed, slightly disturbed, strongly disturbed - folded, desintegrated, sheared), the proportion of siltstones against sandstones and the expressed or not stratification inside the siltstone layers. In the type IV and V when the thickness of sandstone beds exceed 50cm an increase of the GSI value by 5 is suggested. From type IV and the following types, the stratification planes are perceptible inside the siltstone mass. Locate the position in the box that corresponds to the conditions and estimate the average value GSI from the contours. The determination of the structure and the condition of discontinuities may range between two adjacent fields. Note that the Hoek - Brown criterion does not apply to structurally controlled failures. Where unfavourably oriented continuous weak planar discontinuities are present, these will dominate the behaviour of the rock mass. The strength of some rock masses is reduced by the presence of groundwater and this can be allowed for by a slight shift to the right in the columns for fair, poor and very poor conditions. Water pressure does not change the value of GSI and it is dealt with by using effective stress analysis.</p>		VERY GOOD Very rough, fresh unweathered surfaces	VERY POOR Very smooth, slickensided or highly weathered surfaces with soft clay coating or fillings
		GOOD Rough, slightly weathered or oxidised surfaces	VERY POOR Very smooth, slickensided or highly weathered surfaces with soft clay coating or fillings
STRUCTURE AND COMPOSITION		DECREASE OF THE QUALITY OF DISCONTINUITIES →	
TYPE I. Undisturbed, with thick to medium thickness sandstone beds with sporadic thin films of siltstone. In shallow tunnels or slopes where confinement is poor the mode of the failure has a kinematic character controlled by the bedding planes and GSI is meaningless	TYPE II. Undisturbed massive siltstone (stratification planes are imperceptible) with sporadic thin interlayers of sandstones	80	I II N/A N/A
TYPE III. Moderately disturbed sandstones with thin films of interlayers of siltstone	TYPE IV. Moderately disturbed rockmass with sandstone and siltstone similar amounts	70	III IV V VI N/A
TYPE V. Moderately disturbed siltstones with sandstone interlayers	TYPE VI. Moderately disturbed siltstones with sparse sandstone interlayers	60	III IV V VI N/A
TYPE VII. Strongly disturbed, folded rockmass that retains its structure, with sandstone and siltstone in similar extend	TYPE VIII. Strongly disturbed, folded rockmass, with siltstones and sandstone interlayers. The structure is retained and deformation - shearing is not strong	50	III IV V VI N/A
TYPE IX. Desintegrated rockmass that can be found in wide zones of faults or/and of high weathering. In this type mainly brittle material is present with some disturbed siltstones between rock pieces	TYPE X. Tectonically deformed intensively folded/ faulted siltstone or clay shale with broken and deformed sandstone layers forming an almost chaotic structure	40	VII VIII
TYPE XI. Tectonically strongly sheared siltstone or clayey shale forming a chaotic structure with pockets of clay. Thin layers of sandstone are transformed into small rock pieces. Ultimately the ground behavior is that of a soil		30	IX X XI
		20	XI
		10	XI

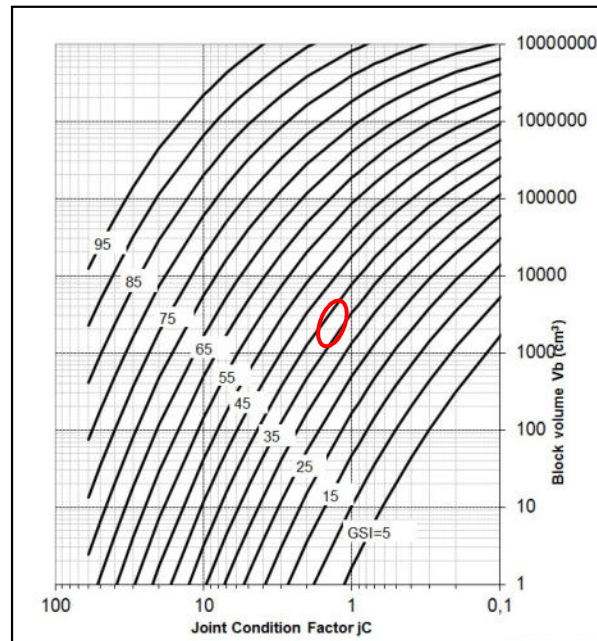
N/A Means geologically impossible combination. In the non - shadowed areas, such rockmasses are not impossible to find but it is very unusual

→ Direction of tectonic disturbance and deformation of equivalent rockmass lithology

GSI: xxx

Determinazione del GSI (Marinos V., 2007)

Relazione sui rilievi geologico strutturali di dettaglio



GSI: 35 - 40

Determinazione del GSI tramite i parametri RMI: jC e Vb. (Russo, 2007)

*RMI: Rock Mass index (Palmstrøm, 1994)

VALUTAZIONE DELLA RESISTENZA A COMPRESIONE UNIASSIALE MEDIANTE SCLEROMETRO (Martello di Schmidt)
ISRM (1978a e 1978b); Miller (1965)

Famiglia	Direzione di applicazione	Indice di rimbalzo (Martello di Schmidt)											
		1	2	3	4	5	6	7	8	9	10	11	12
St		20	14	48	58	36	30	52	42	42	52	52	56
J1		20	12	47	42	22	40	22	42	36	14	22	22
J2		54	52	44	48	50	30	30	40	56	34	31	30

APPENDICE

1_Caratteristiche geomeccaniche delle discontinuità Basic Geotechnical Description (ISRM, 1981)

Characteristics	Id	Typology	Range	
SPACING	S1	Very close spacing	< 6 cm	
	S2	Close spacing	6-20 cm	
	S3	Moderate spacing	20 - 60 cm	
	S4	Wide spacing	60 - 200 cm	
	S5	Very wide spacing	> 200 cm	
PERSISTENCE	P1	Very low persistence	< 1 m	
	P2	Low persistence	1 – 3 m	
	P3	Medium persistence	10 – 20 m	
	P4	High persistence	10 – 20 m	
	P5	Very high persistence	> 20m	
ROUGHNESS	Stepped	R1	Rough (or irregular)	-
		R2	Smooth	-
		R3	Slickenside	-
	Undulating	R4	Rough (or irregular)	-
		R5	Smooth	-
		R6	Slickenside	-
	Planar	R7	Rough (or irregular)	-
		R8	Smooth	-
		R9	Slickenside	-
JOINT CONDITIONS	C1	Fresh	-	
	C2	Slightly weathered	-	
	C3	Moderately weathered	-	
	C4	Highly weathered	-	
	C5	Completely weathered	-	
	C6	Residual soil	-	
APERTURE	A1	Closed	0.0 mm	
	A2	Very tight - Tight	< 0.1 mm	
	A3	Partly open - Open	0.1 mm – 1 mm	
	A4	Open - Moderately wide	1 mm – 5 mm	
	A5	Moderately wide - Wide	> 5mm	

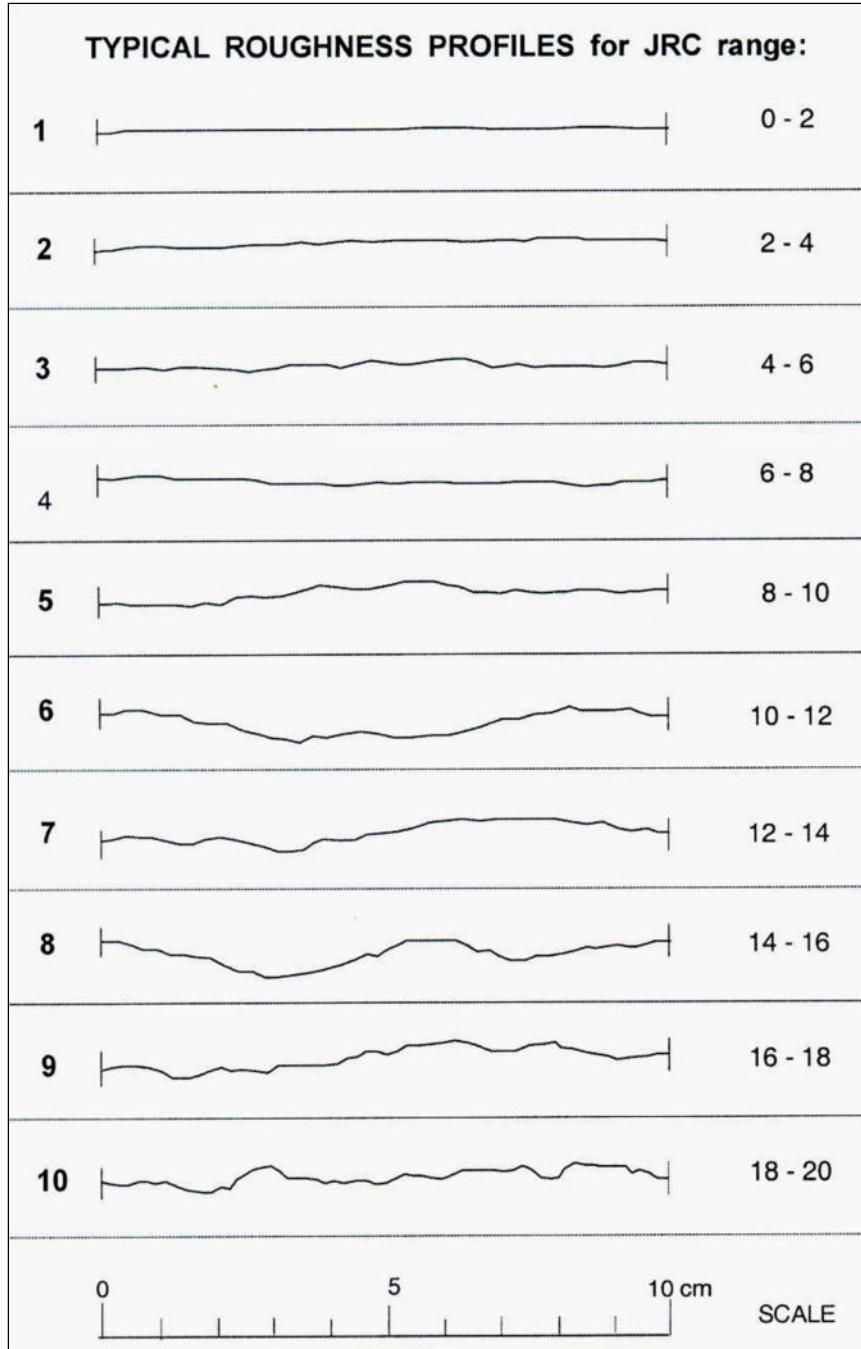
2_Caratteristiche geomeccaniche delle discontinuità

"Ratings" Evaluation – Métod PALMSTRØM (2000 – 2005)

"RATINGS" EVALUATION – MÉTODO PALMSTRØM (2000 - 2005)						
Joint Condition Factor j_C		$j_C \text{ (Palmstrøm)} = j_R \times j_L / j_A$				
Joint roughness factor (j_R)		Large scale waviness of joint plane				
		Planar	Slightly undulating	Undulating	Strongly undulating	Stepped or Interlocking
small scale smoothness of joint surface	Very rough	2	3	4	6	6
	Rough	1,5	2	3	4,5	6
	Smooth	1	1,5	2	3	4
	Polished or slickenside *	0,5	1	1,5	2	3
For filled joint $j_R=1$. For irregular joint a rating of $j_R=5$ is suggested						
*) for slickenside surfaces the rating apply to possible movement along the lineations.						
Joint alteration factor (j_A)						
Contact between joint walls	Joint wall character		Condition		Wall contact	
	CLEAN JOINTS	Healed or welded joints	filling of quartz, epidote, etc.		0,75	
		Fresh joint walls	no coating or filling, except from staining (rust)		1	
		Altered joint walls	one grade higher alteration than the rock		2	
	two grades higher alteration than the rock		4			
	COATING or THIN FILLING	Friction materials	sand, silt calcite, etc. without content of clay		3	
Cohesive materials		clay, chlorite, talc, etc.		4		
Partly or no wall contact	Filling	Type	Party wall contact	No wall contact		
			thin filling (<5mm)	thick filling or gouge		
	Friction materials	sand, silt calcite, etc. (non softening)	4	8		
	Hard, cohesive materials	compacted filling of clay, chlorite, talc, etc.	6	6-10		
	Soft, cohesive materials	medium to low ever consolidated clay, chlorite, talc, etc.	8	12		
Swelling clay materials	filling material exhibits swelling properties	8-12	13-20			
Joint size factor (j_L)						
Type	Length	Size	Continuous joints	Discontin. Joints *		
Bedding or foliation partings	<0,5 m	Very short	3	6		
	0,1-1 m	short or small	2	4		
		medium	1	2		
		long or large	0,75	1,5		
(Filled) joint, seam or shear **	>30 m	very long or large	0,50	1		
*) Discontinuous joints end in massive rock			**) Often a singularity and should in these cases be treated separately			

3_Profilo tipici di scabrezza (rugosità)

Barton & Choubey, 1977



RILIEVO GEOSTRUTTURALE

Codice rilievo:	RS_04	Coordinate UTM-WGS 84 (33T)		Quota [m s.l.m.]
Rilevatore:	Fassone A.	324759 E	4736335 N	313
Data:	19/10/22	Azimut della parete rocciosa: N350		
Comune:	Vallo di Nera	Litologia: Scaglia Rossa		
Località:	Piedipaterno	Note: Affioramento lungo strada in prossimità del Municipio provvisorio di Vallo di Nera		

PLANIMETRIA DI UBICAZIONE

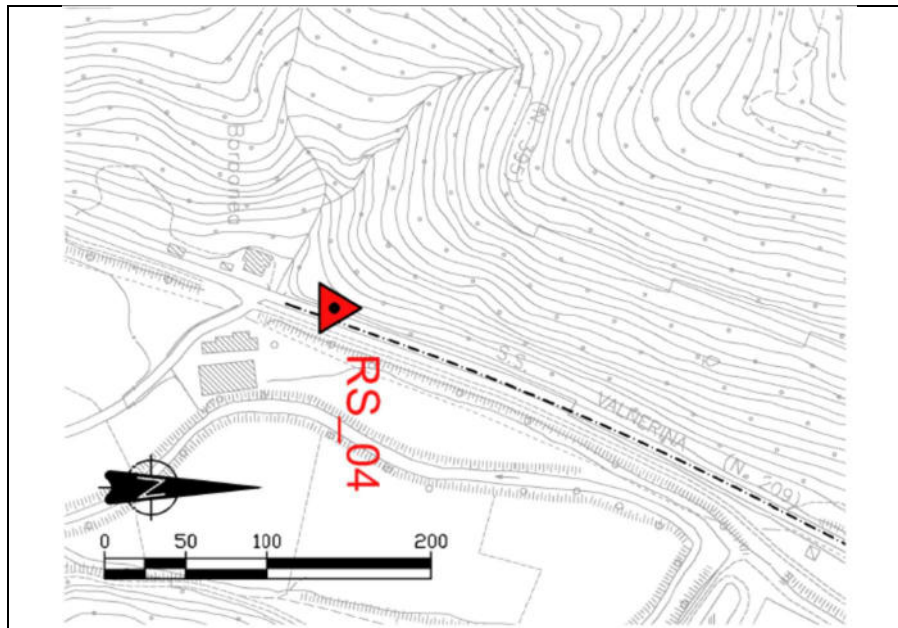


Fig.1. Carta di localizzazione del rilievo strutturale

DOCUMENTAZIONE FOTOGRAFICA



Fig.2. Vista d'insieme dell'affioramento

DESCRIZIONE DELL’AFFIORAMENTO

Affioramento roccioso: Scaglia Rossa (Turoniano inferiore - Eocene medio)
 L’ammasso si presenta fratturato e contraddistinto da fratture lungo i piani di stratificazione (St) e da cinque famiglie di discontinuità principali, di cui alcune associate a sistemi di faglia (St=J1, J2=F2, J3=F3, J4). Le fratture, in maggioranza aperte, con superfici da moderatamente alterate ad alterate, in alcuni casi riempite da materiale residuale. L’affioramento si presenta privo di emergenze idriche.

Dimensione blocchi

Minima: 8 x 8 x 10 [cm]; **Massima:** 90 x 50 x 80 [cm]; **Frequente:** 40 x 20 x 60 [cm];

Spessore roccia affiorante: 3,00 – 4,50 m

Note: Settore deformato, caratterizzato dalla presenza discontinuità tettoniche (faglie).

CARATTERISTICHE GEOMECCANICHE DELLE DISCONTINUITA’
International Society for Rock Mechanics - ISRM (1981)
BGD (Basic Geotechnical Description)

Famiglia	Orientazione		Caratteristiche delle discontinuità							
	Imm.	Incl.	Spaziatura	Persistenza	Rugosità	Grado di alterazione	Apertura	Riempimento	Condizioni Idrauliche	JRC
St=J1	210	76	S3 (S4)	P3	R4	C3	A4 (A3)	F6	Secco	8-10
F1	200	60	S4 (S5)	P2 (P3)	R6	C3 (C4)	A5	F8	Secco	6-8
F2=J2	310	60	S4 (S3)	P3	R6	C4 (C4)	A3	-	Secco	6-8
F3=J3	110	70	S2 (S3)	P3	R4	C3	A2 (A3)	-	Secco	8-10
J4	10	80	S4	P2	R4	C3	A5	-	Secco	8-10

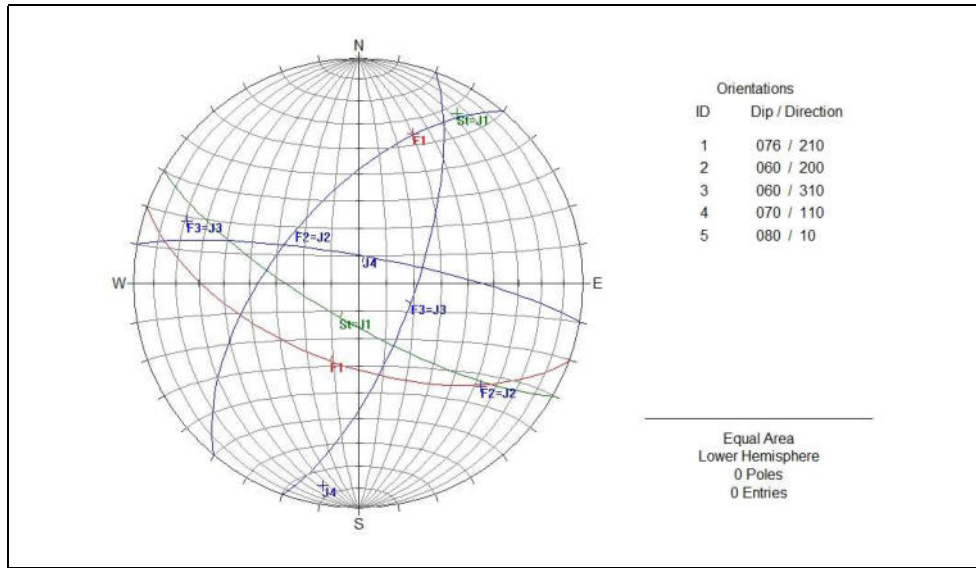
Note:

- St: Stratificazione; J: Giunto, frattura; F: Faglia, discontinuità tettonica.
- I termini tra parentesi descrivono caratteristiche subordinate.

CARATTERISTICHE GEOMECCANICHE DELLE DISCONTINUITA’
"Ratings" Evaluation – Metod PALMSTRØM (2000 – 2005)

Famiglia	Joint Condition jC (Palmstrøm) = jR x jL /jA		
	jR	jL	JA
St=J1	2	1	2
F1	1	2	3
F2=J2	1	1	4
F3=J3	2	1	2
J4	3	2	3

PROIEZIONE STEREOGRAFICA DELLE DISCONTINUITA'



VOLUME DEI BLOCCHI (V_b) E FATTORE DI FORMA DEL BLOCCO (β)
Palmstrøm (2005)

Volume dei blocchi (V_b) – misurati visivamente in sito [cm ³]				Fattore di forma del blocco	
Dimensione dei blocchi	Frequente	Min	Max	Palmstrøm, 2005	
				Extremely lung or flat blocks	Beta (β)
L1 [cm]	40	8	90	Very long or flat blocks	100 - 500
L2 [cm]	20	10	50	Moderately long or flat blocks	50 - 100
L3 [cm]	65	8	80	Slightly long or flat blocks	32 - 50
$V_b = L1 \times L2 \times L3$	52000	640	360000	Cubical blocks	27 - 32

VALUTAZIONE DEL GSI (GEOLOGICAL STRAIN INDEX)

Hoek and Marinos P. (2000) – Determinazione GSI per rocce fratturate

Marinos V. (2007) – Determinazione GSI per rocce flyschoidi

Russo (2007) – Determinazione GSI tramite i parametri RMI: jC e Vb. *

GEOLOGICAL STRENGTH INDEX FOR JOINTED ROCKS (Hoek and Marinos, 2000)		SURFACE CONDITIONS	
<p>From the lithology, structure and surface conditions of the discontinuities, estimate the average value of GSI. Do not try to be too precise. Quoting a range from 33 to 37 is more realistic than stating that GSI = 35. Note that the table does not apply to structurally controlled failures. Where weak planar structural planes are present in an unfavourable orientation with respect to the excavation face, these will dominate the rock mass behaviour. The shear strength of surfaces in rocks that are prone to deterioration as a result of changes in moisture content will be reduced if water is present. When working with rocks in the fair to very poor categories, a shift to the right may be made for wet conditions. Water pressure is dealt with by effective stress analysis.</p>		SURFACE CONDITIONS	
		VERY GOOD Very rough, fresh unweathered surfaces	GOOD Rough, slightly weathered, iron stained surfaces
STRUCTURE		FAIR Smooth, moderately weathered and altered surfaces	
DECREASING SURFACE QUALITY →		POOR Sticksensided, highly weathered surfaces with compact coatings or fillings or angular fragments	
DECREASING INTERLOCKING OF ROCK PIECES		VERY POOR Sticksensided, highly weathered surfaces with soft clay coatings or fillings	
INTACT OR MASSIVE - intact rock specimens or massive in situ rock with few widely spaced discontinuities	90	N/A	N/A
BLOCKY - well interlocked undisturbed rock mass consisting of cubical blocks formed by three intersecting discontinuity sets	80	70	60
VERY BLOCKY - interlocked, partially disturbed mass with multi-faceted angular blocks formed by 4 or more joint sets	70	60	50
BLOCKY/DISTURBED/SEAMY - folded with angular blocks formed by many intersecting discontinuity sets. Persistence of bedding planes or schistosity	60	50	40
DISINTEGRATED - poorly interlocked, heavily broken rock mass with mixture of angular and rounded rock pieces	50	40	30
LAMINATED/SHEARED - Lack of blockiness due to close spacing of weak schistosity or shear planes	40	30	20
	30	20	10
	N/A	N/A	10

GSI: 40 - 45

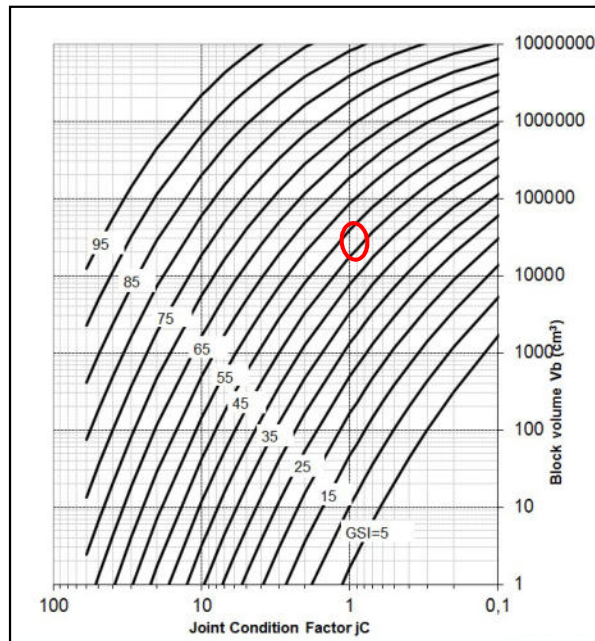
Determinazione del GSI (Hoek and Marinos P., 2000)

GEOLOGICAL STRENGTH INDEX (GSI) FOR HETEROGENEOUS ROCK MASSES SUCH AS FLYSCH (V. Marinos, 2007)		SURFACE CONDITIONS OF DISCONTINUITIES (Predominantly bedding planes)	
<p>Heterogeneous rockmasses are meant those with alternating layers of clearly different lithology types with significant differences in their strength properties. For flysch, a typical formation with heterogeneous rock masses, these alternations are consisting of sandstones and siltstones. Clay shales may be present. From a description of the lithology, structure and surface conditions of discontinuities (particularly of the bedding planes), choose a box in the chart. The selection of the structure should be based on the tectonic disturbance (undisturbed, slightly disturbed, strongly disturbed - folded, desintegrated, sheared), the proportion of siltstones against sandstones and the expressed or not stratification inside the siltstone layers. In the type IV and V when the thickness of sandstone beds exceed 50cm an increase of the GSI value by 5 is suggested. From type IV and the following types, the stratification planes are perceptible inside the siltstone mass. Locate the position in the box that corresponds to the conditions and estimate the average value GSI from the contours. The determination of the structure and the condition of discontinuities may range between two adjacent fields. Note that the Hoek - Brown criterion does not apply to structurally controlled failures. Where unfavourably oriented continuous weak planar discontinuities are present, these will dominate the behaviour of the rock mass. The strength of some rock masses is reduced by the presence of groundwater and this can be allowed for by a slight shift to the right in the columns for fair, poor and very poor conditions. Water pressure does not change the value of GSI and it is dealt with by using effective stress analysis.</p>		SURFACE CONDITIONS OF DISCONTINUITIES (Predominantly bedding planes)	
		VERY GOOD Very rough, fresh unweathered surfaces	GOOD Rough, slightly weathered or oxidised surfaces
STRUCTURE AND COMPOSITION		DECREASE OF THE QUALITY OF DISCONTINUITIES →	
TYPE I. Undisturbed, with thick to medium thickness sandstone beds with sporadic thin films of siltstone. In shallow tunnels or slopes where confinement is poor the mode of the failure has a kinematic character controlled by the bedding planes and GSI is meaningless	TYPE II. Undisturbed massive siltstone (stratification planes are imperceptible) with sporadic thin interlayers of sandstones	80	I II N/A N/A
TYPE III. Moderately disturbed sandstones with thin films of interlayers of siltstone	TYPE IV. Moderately disturbed rockmass with sandstone and siltstone similar amounts	70	III IV V VI N/A
TYPE V. Moderately disturbed siltstones with sandstone interlayers	TYPE VI. Moderately disturbed siltstones with sparse sandstone interlayers	60	III IV V VI N/A
TYPE VII. Strongly disturbed, folded rockmass that retains its structure, with sandstone and siltstone in similar extend	TYPE VIII. Strongly disturbed, folded rockmass, with siltstones and sandstone interlayers. The structure is retained and deformation - shearing is not strong	50	III IV V VI N/A
TYPE IX. Desintegrated rockmass that can be found in wide zones of faults or/and of high weathering. In this type mainly brittle material is present with some disturbed siltstones between rock pieces	TYPE X. Tectonically deformed intensively folded/ faulted siltstone or clay shale with broken and deformed sandstone layers forming an almost chaotic structure	40	VII VIII
TYPE XI. Tectonically strongly sheared siltstone or clayey shale forming a chaotic structure with pockets of clay. Thin layers of sandstone are transformed into small rock pieces. Ultimately the ground behavior is that of a soil		30	IX X XI
		20	IX X XI
		10	XI

GSI: xxx

Determinazione del GSI (Marinos V., 2007)

Relazione sui rilievi geologico strutturali di dettaglio







GSI: 45 -50

Determinazione del GSI tramite i parametri RMi: jC e Vb. (Russo, 2007)

*RMi: Rock Mass index (Palmstrøm, 1994)

VALUTAZIONE DELLA RESISTENZA A COMPRESIONE UNIASSIALE MEDIANTE SCLEROMETRO (Martello di Schmidt)
ISRM (1978a e 1978b); Miller (1965)

Famiglia	Direzione di applicazione	Indice di rimbalzo (Martello di Schmidt)											
		1	2	3	4	5	6	7	8	9	10	11	12
St=J1		20	26	32	44	52	26	56	36	40	50	46	34
F2=J2		42	22	20	48	30	32	42	41	30	38	28	42
F3=J3		38	38	54	40	20	56	42	20	20	40	52	46
J4		36	50	50	40	36	42	20	20	40	52	46	42

APPENDICE

1_Caratteristiche geomeccaniche delle discontinuità Basic Geotechnical Description (ISRM, 1981)

Characteristics	Id	Typology	Range	
SPACING	S1	Very close spacing	< 6 cm	
	S2	Close spacing	6-20 cm	
	S3	Moderate spacing	20 - 60 cm	
	S4	Wide spacing	60 - 200 cm	
	S5	Very wide spacing	> 200 cm	
PERSISTENCE	P1	Very low persistence	< 1 m	
	P2	Low persistence	1 – 3 m	
	P3	Medium persistence	10 – 20 m	
	P4	High persistence	10 – 20 m	
	P5	Very high persistence	> 20m	
ROUGHNESS	Stepped	R1	Rough (or irregular)	-
		R2	Smooth	-
		R3	Slickenside	-
	Undulating	R4	Rough (or irregular)	-
		R5	Smooth	-
		R6	Slickenside	-
	Planar	R7	Rough (or irregular)	-
		R8	Smooth	-
		R9	Slickenside	-
JOINT CONDITIONS	C1	Fresh	-	
	C2	Slightly weathered	-	
	C3	Moderately weathered	-	
	C4	Highly weathered	-	
	C5	Completely weathered	-	
	C6	Residual soil	-	
APERTURE	A1	Closed	0.0 mm	
	A2	Very tight - Tight	< 0.1 mm	
	A3	Partly open - Open	0.1 mm – 1 mm	
	A4	Open - Moderately wide	1 mm – 5 mm	
	A5	Moderately wide - Wide	> 5mm	

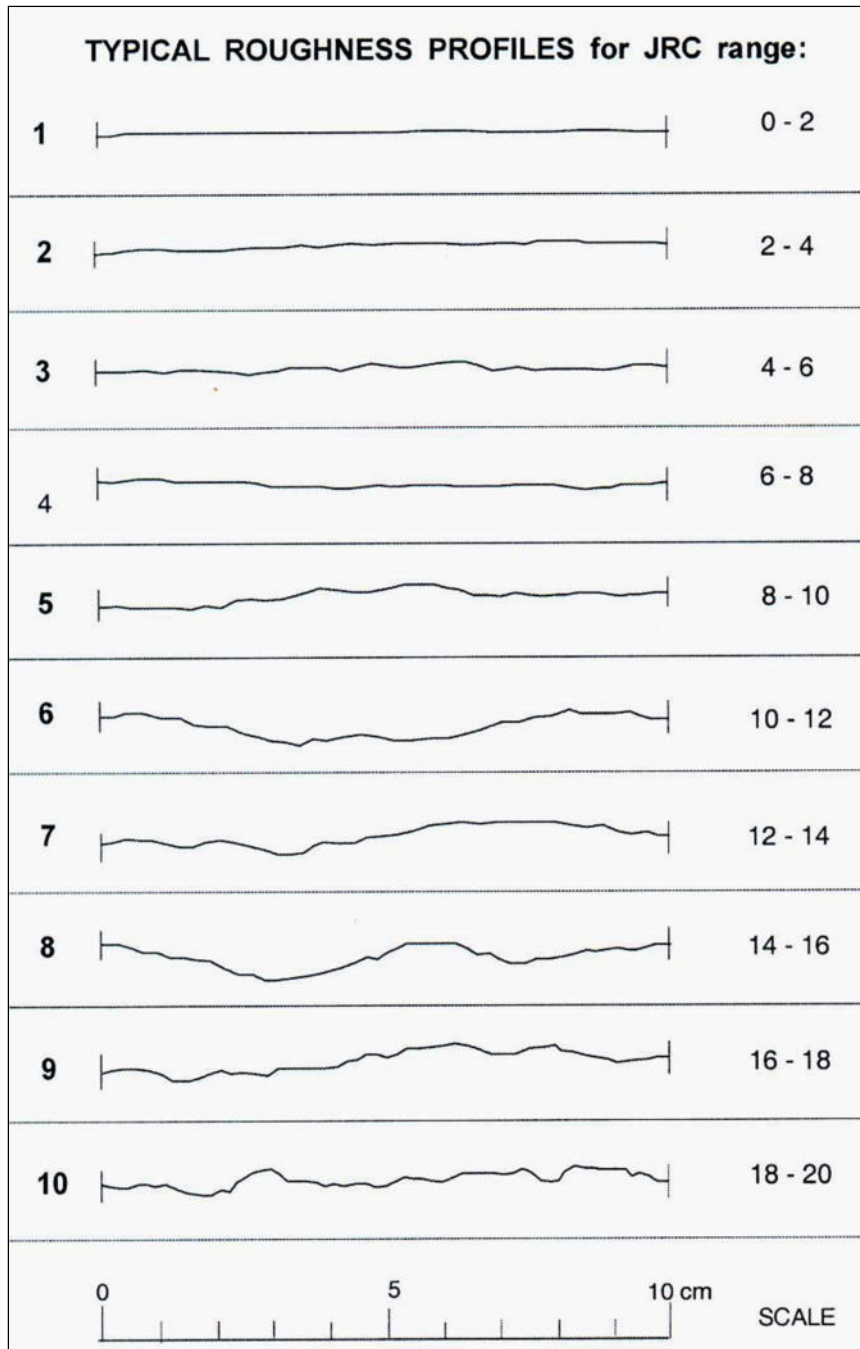
2_Caratteristiche geomeccaniche delle discontinuità

"Ratings" Evaluation – Métod PALMSTRØM (2000 – 2005)

"RATINGS" EVALUATION – MÉTODO PALMSTRØM (2000 - 2005)						
Joint Condition Factor j_C		$j_C \text{ (Palmstrøm)} = j_R \times j_L / j_A$				
Joint roughness factor (j_R)		Large scale waviness of joint plane				
		Planar	Slightly undulating	Undulating	Strongly undulating	Stepped or Interlocking
small scale smoothness of joint surface	Very rough	2	3	4	6	6
	Rough	1,5	2	3	4,5	6
	Smooth	1	1,5	2	3	4
	Polished or slickenside *	0,5	1	1,5	2	3
For filled joint $j_R=1$. For irregular joint a rating of $j_R=5$ is suggested						
*) for slickenside surfaces the rating apply to possible movement along the lineations.						
Joint alteration factor (j_A)						
Contact between joint walls	Joint wall character		Condition		Wall contact	
	CLEAN JOINTS	Healed or welded joints	filling of quartz, epidote, etc.		0,75	
		Fresh joint walls	no coating or filling, except from staining (rust)		1	
		Altered joint walls	one grade higher alteration than the rock		2	
	two grades higher alteration than the rock		4			
	COATING or THIN FILLING	Friction materials	sand, silt calcite, etc. without content of clay		3	
Cohesive materials		clay, chlorite, talc, etc.		4		
Partly or no wall contact	Filling	Type	Party wall contact	No wall contact		
			thin filling (<5mm)	thick filling or gouge		
	Friction materials	sand, silt calcite, etc. (non softening)	4	8		
	Hard, cohesive materials	compacted filling of clay, chlorite, talc, etc.	6	6-10		
	Soft, cohesive materials	medium to low ever consolidated clay, chlorite, talc, etc.	8	12		
Swelling clay materials	filling material exhibits swelling properties	8-12	13-20			
Joint size factor (j_L)						
Type	Length	Size	Continuous joints	Discontin. Joints *		
Bedding or foliation partings	<0,5 m	Very short	3	6		
	0,1-1 m	short or small	2	4		
		medium	1	2		
		long or large	0,75	1,5		
(Filled) joint, seam or shear **	>30 m	very long or large	0,50	1		
*) Discontinuous joints end in massive rock			**) Often a singularity and should in these cases be treated separately			

3_Profilo tipici di scabrezza (rugosità)

Barton & Choubey, 1977



RILIEVO GEOSTRUTTURALE

Codice rilievo:	RS_05	Coordinate UTM-WGS 84 (33T)		Quota [m s.l.m.]
Rilevatore:	Fassone A.	325457 E	4737978 N	323
Data:	19/10/22	Azimut della parete rocciosa: N10		
Comune:	Vallo di Nera	Litologia: Scaglia Rossa		
Località:		Note:		

PLANIMETRIA DI UBICAZIONE

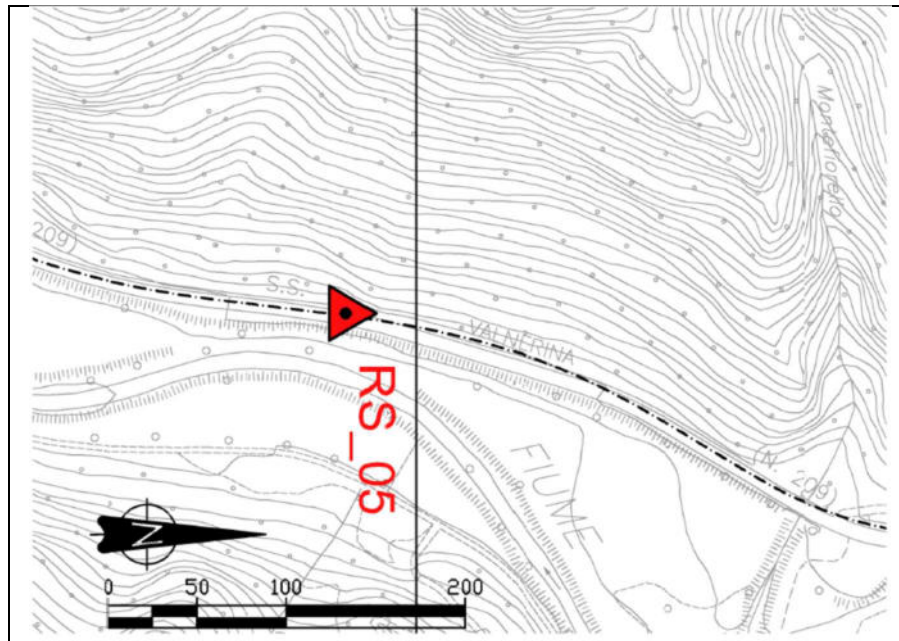


Fig.1. Carta di localizzazione del rilievo strutturale

DOCUMENTAZIONE FOTOGRAFICA



Fig.2. Vista d'insieme dell'affioramento

DESCRIZIONE DELL’AFFIORAMENTO

Affioramento roccioso: Scaglia Rossa (Turoniano inferiore - Eocene medio)
L’ammasso si presenta fratturato e contraddistinto da quattro famiglie di discontinuità principali (J1, J2, J3, J4). Le fratture, generalmente aperte, risultano persistenti, con superfici moderatamente alterate. L’affioramento si presenta privo di emergenze idriche.

Dimensione blocchi

Minima: 8 x 10 x 6 [cm]; **Massima:** 70 x 80 x 80 [cm]; **Frequente:** 30 x 40 x 40 [cm];

Spessore roccia affiorante: 6,00 – 10m

Note:

CARATTERISTICHE GEOMECCANICHE DELLE DISCONTINUITA’
International Society for Rock Mechanics - ISRM (1981)
BGD (Basic Geotechnical Description)

Famiglia	Orientazione		Caratteristiche delle discontinuità							
	Imm.	Incl.	Spaziatura	Persistenza	Rugosità	Grado di alterazione	Apertura	Riempimento	Condizioni Idrauliche	JRC
J1	180	68	S3 (S4)	P3 (P4)	R4	C4 (C3)	A5 (A4)	F7	secco	8-10
F=J2	70	34	S3	P3 (P2)	R4 (R6)	C3	A1	-	secco	6-8
J3	100	88	S3 (S2)	P3	R4	C3	A2	-	secco	8-10
J4	198	66	S3	P3	R4	C4	A5	-	secco	8-10

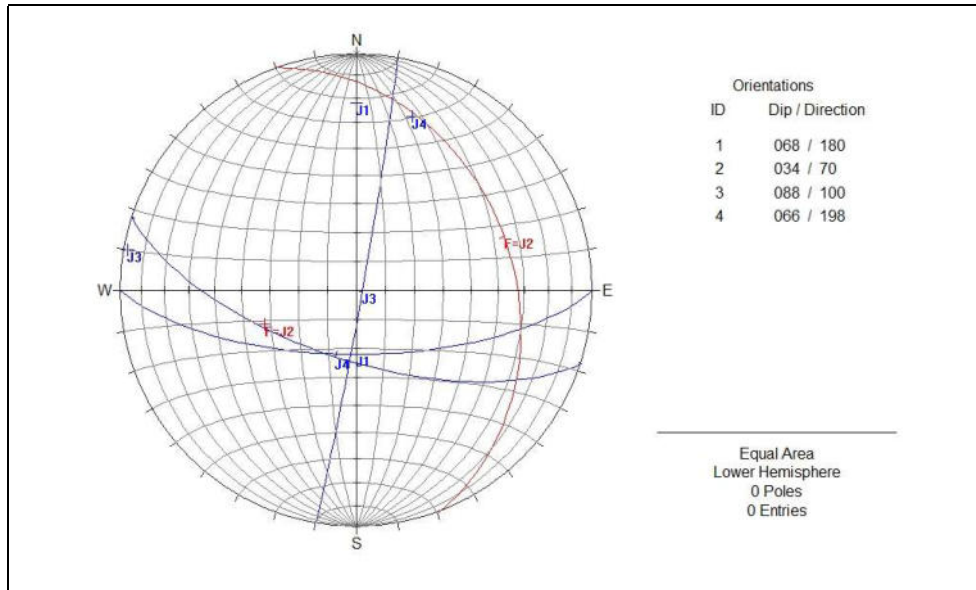
Note:

- St: Stratificazione; J: Giunto, frattura; F: Faglia, discontinuità tettonica.
- I termini tra parentesi descrivono caratteristiche subordinate.

CARATTERISTICHE GEOMECCANICHE DELLE DISCONTINUITA’
"Ratings" Evaluation – Métod PALMSTRØM (2000 – 2005)

Famiglia	Joint Condition jC (Palmstrøm) = $jR \times jL / jA$		
	jR	jL	jA
J1	2	1	3
F=J2	1	1	2
J3	2	1	2
J4	2	1	2

PROIEZIONE STEREOGRAFICA DELLE DISCONTINUITA'



VOLUME DEI BLOCCHI (V_b) E FATTORE DI FORMA DEL BLOCCO (β)
Palmstrøm (2005)

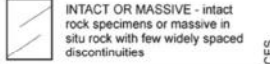
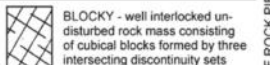
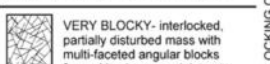
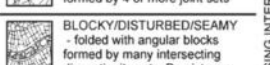
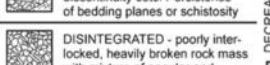
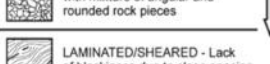
Volume dei blocchi (V_b) – misurati visivamente in sito [cm ³]				Fattore di forma del blocco	
Dimensione dei blocchi	Frequente	Min	Max	Palmstrøm, 2005	Beta (β)
				Extremely lung or flat blocks	>500
L1 [cm]	30	8	70	Very long or flat blocks	100 - 500
L2 [cm]	40	10	80	Moderately long or flat blocks	50 - 100
L3 [cm]	40	6	80	Slightly long or flat blocks	32 - 50
$V_b = L1 \times L2 \times L3$	48000	480	448000	Cubical blocks	27 - 32

VALUTAZIONE DEL GSI (GEOLOGICAL STRAIN INDEX)

Hoek and Marinos P. (2000) – Determinazione GSI per rocce fratturate

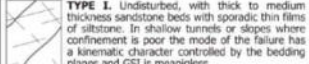
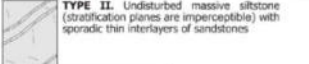


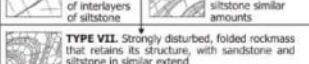


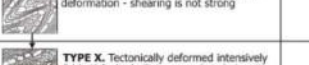
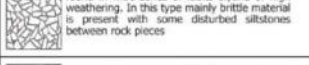
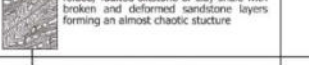
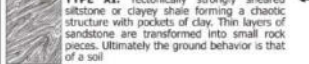
Marinos V. (2007) – Determinazione GSI per rocce flyschoidi

Russo (2007) – Determinazione GSI tramite i parametri RMI: jC e Vb. *

GEOLOGICAL STRENGTH INDEX FOR JOINTED ROCKS (Hoek and Marinos, 2000)		SURFACE CONDITIONS	
<p>From the lithology, structure and surface conditions of the discontinuities, estimate the average value of GSI. Do not try to be too precise. Quoting a range from 33 to 37 is more realistic than stating that GSI = 35. Note that the table does not apply to structurally controlled failures. Where weak planar structural planes are present in an unfavourable orientation with respect to the excavation face, these will dominate the rock mass behaviour. The shear strength of surfaces in rocks that are prone to deterioration as a result of changes in moisture content will be reduced if water is present. When working with rocks in the fair to very poor categories, a shift to the right may be made for wet conditions. Water pressure is dealt with by effective stress analysis.</p>		VERY GOOD Very rough, fresh unweathered surfaces	VERY POOR Slickensided, highly weathered surfaces with soft clay coatings or fillings
		GOOD Rough, slightly weathered, iron stained surfaces	VERY POOR Slickensided, highly weathered surfaces with soft clay coatings or fillings
STRUCTURE		DECREASING SURFACE QUALITY →	
 <p>INTACT OR MASSIVE - intact rock specimens or massive in situ rock with few widely spaced discontinuities</p>	90	N/A	N/A
 <p>BLOCKY - well interlocked undisturbed rock mass consisting of cubical blocks formed by three intersecting discontinuity sets</p>	80	70	N/A
 <p>VERY BLOCKY - interlocked, partially disturbed mass with multi-faceted angular blocks formed by 4 or more joint sets</p>	70	60	50
 <p>BLOCKY/DISTURBED/SEAMY - folded with angular blocks formed by many intersecting discontinuity sets. Persistence of bedding planes or schistosity</p>	60	50	40
 <p>DISINTEGRATED - poorly interlocked, heavily broken rock mass with mixture of angular and rounded rock pieces</p>	50	40	30
 <p>LAMINATED/SHEARED - Lack of blockiness due to close spacing of weak schistosity or shear planes</p>	40	30	20
	30	20	10
	20	10	N/A
	10	N/A	N/A

GSI: 45 - 50

Determinazione del GSI (Hoek and Marinos P., 2000)

GEOLOGICAL STRENGTH INDEX (GSI) FOR HETEROGENEOUS ROCK MASSES SUCH AS FLYSCH (V. Marinos, 2007)		SURFACE CONDITIONS OF DISCONTINUITIES (Predominantly bedding planes)			
<p>Heterogeneous rockmasses are meant those with alternating layers of clearly different lithology types with significant differences in their strength properties. For flysch, a typical formation with heterogeneous rock masses, these alternations are consisting of sandstones and siltstones. Clay shales may be present. From a description of the lithology, structure and surface conditions of discontinuities (particularly of the bedding planes), choose a box in the chart. The selection of the structure should be based on the tectonic disturbance (undisturbed, slightly disturbed, strongly disturbed - folded, desintegrated, sheared), the proportion of siltstones against sandstones and the expressed or not stratification inside the siltstone layers. In the type IV and V when the thickness of sandstone beds exceed 50cm an increase of the GSI value by 5 is suggested. From type IV and the following types, the stratification planes are perceptible inside the siltstone mass. Locate the position in the box that corresponds to the conditions and estimate the average value GSI from the contours. The determination of the structure and the condition of discontinuities may range between two adjacent fields. Note that the Hoek - Brown criterion does not apply to structurally controlled failures. Where unfavourably oriented continuous weak planar discontinuities are present, these will dominate the behaviour of the rock mass. The strength of some rock masses is reduced by the presence of groundwater and this can be allowed for by a slight shift to the right in the columns for fair, poor and very poor conditions. Water pressure does not change the value of GSI and it is dealt with by using effective stress analysis.</p>		VERY GOOD Very rough, fresh unweathered surfaces	VERY POOR Very smooth, slickensided or highly weathered surfaces with soft clay coating or fillings		
		GOOD Rough, slightly weathered or oxidised surfaces	VERY POOR Very smooth, slickensided or highly weathered surfaces with soft clay coating or fillings		
STRUCTURE AND COMPOSITION		DECREASE OF THE QUALITY OF DISCONTINUITIES →			
 <p>TYPE I. Undisturbed, with thick to medium thickness sandstone beds with sporadic thin films of siltstone. In shallow tunnels or slopes where confinement is poor the mode of the failure has a kinematic character controlled by the bedding planes and GSI is meaningless</p>	80	I	II	N/A	N/A
 <p>TYPE II. Undisturbed massive siltstone (stratification planes are imperceptible) with sporadic thin interlayers of sandstones</p>	70	I	II	N/A	N/A
 <p>TYPE III. Moderately disturbed sandstones with thin films of interlayers of siltstone</p>	60	III	IV	V	VI
 <p>TYPE IV. Moderately disturbed rockmass with sandstone and siltstone similar amounts</p>	50	III	IV	V	VI
 <p>TYPE V. Moderately disturbed siltstones with sandstone interlayers</p>	40	III	IV	V	VI
 <p>TYPE VI. Moderately disturbed siltstones with sparse sandstone interlayers</p>	30	III	IV	V	VI
 <p>TYPE VII. Strongly disturbed, folded rockmass that retains its structure, with sandstone and siltstone in similar extend</p>	N/A	N/A	VII	VIII	N/A
 <p>TYPE VIII. Strongly disturbed, folded rockmass, with siltstones and sandstone interlayers. The structure is retained and deformation - shearing is not strong</p>	N/A	N/A	VII	VIII	N/A
 <p>TYPE IX. Desintegrated rockmass that can be found in wide zones of faults or/and of high weathering. In this type mainly brittle material is present with some disturbed siltstones between rock pieces</p>	N/A	N/A	IX	X	N/A
 <p>TYPE X. Tectonically deformed intensively folded/ faulted siltstone or clay shale with broken and deformed sandstone layers forming an almost chaotic structure</p>	N/A	N/A	IX	X	N/A
 <p>TYPE XI. Tectonically strongly sheared siltstone or clayey shale forming a chaotic structure with pockets of clay. Thin layers of sandstone are transformed into small rock pieces. Ultimately the ground behavior is that of a soil</p>	N/A	N/A	N/A	N/A	XI

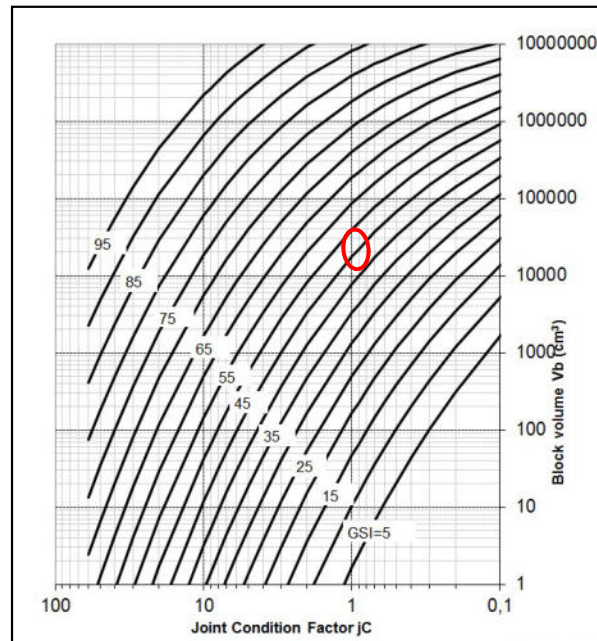
N/A Means geologically impossible combination. In the non - shadowed areas, such rockmasses are not impossible to find but it is very unusual

→ Direction of tectonic disturbance and deformation of equivalent rockmass lithology

GSI: xxx

Determinazione del GSI (Marinos V., 2007)

Relazione sui rilievi geologico strutturali di dettaglio







GSI: 45 -50

Determinazione del GSI tramite i parametri Rmi: jC e Vb. (Russo, 2007)

*Rmi: Rock Mass index (Palmstrøm, 1994)

VALUTAZIONE DELLA RESISTENZA A COMPRESIONE UNIASSIALE MEDIANTE SCLEROMETRO (Martello di Schmidt)
ISRM (1978a e 1978b); Miller (1965)

Famiglia	Direzione di applicazione	Indice di rimbalzo (Martello di Schmidt)											
		1	2	3	4	5	6	7	8	9	10	11	12
J1		28	50	30	26	40	38	42	46	52	40	26	22
F=J2		24	44	38	50	42	46	52	48	51	46	54	42
J3		32	40	20	36	40	26	46	58	54	38	36	44
J4		40	36	28	26	26	42	38	28	40	24	26	36

APPENDICE

1_Caratteristiche geomeccaniche delle discontinuità Basic Geotechnical Description (ISRM, 1981)

Characteristics	Id	Typology	Range	
SPACING	S1	Very close spacing	< 6 cm	
	S2	Close spacing	6-20 cm	
	S3	Moderate spacing	20 - 60 cm	
	S4	Wide spacing	60 - 200 cm	
	S5	Very wide spacing	> 200 cm	
PERSISTENCE	P1	Very low persistence	< 1 m	
	P2	Low persistence	1 – 3 m	
	P3	Medium persistence	10 – 20 m	
	P4	High persistence	10 – 20 m	
	P5	Very high persistence	> 20m	
ROUGHNESS	Stepped	R1	Rough (or irregular)	-
		R2	Smooth	-
		R3	Slickenside	-
	Undulating	R4	Rough (or irregular)	-
		R5	Smooth	-
		R6	Slickenside	-
	Planar	R7	Rough (or irregular)	-
		R8	Smooth	-
		R9	Slickenside	-
JOINT CONDITIONS	C1	Fresh	-	
	C2	Slightly weathered	-	
	C3	Moderately weathered	-	
	C4	Highly weathered	-	
	C5	Completely weathered	-	
	C6	Residual soil	-	
APERTURE	A1	Closed	0.0 mm	
	A2	Very tight - Tight	< 0.1 mm	
	A3	Partly open - Open	0.1 mm – 1 mm	
	A4	Open - Moderately wide	1 mm – 5 mm	
	A5	Moderately wide - Wide	> 5mm	

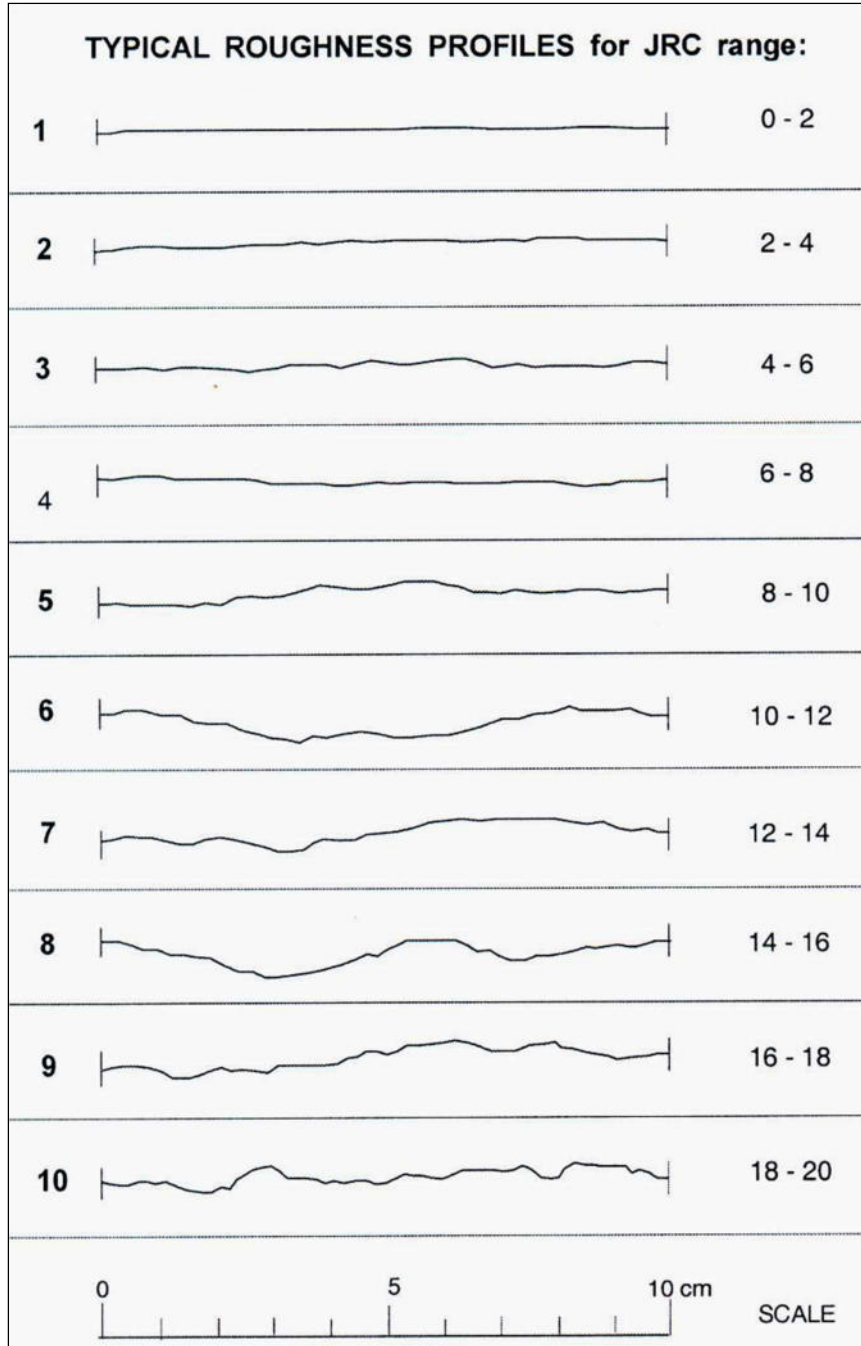
2_Caratteristiche geomeccaniche delle discontinuità

"Ratings" Evaluation – Métod PALMSTRØM (2000 – 2005)

"RATINGS" EVALUATION – MÉTODO PALMSTRØM (2000 - 2005)						
Joint Condition Factor j_C		$j_C \text{ (Palmstrøm)} = j_R \times j_L / j_A$				
Joint roughness factor (j_R)		Large scale waviness of joint plane				
		Planar	Slightly undulating	Undulating	Strongly undulating	Stepped or Interlocking
small scale smoothness of joint surface	Very rough	2	3	4	6	6
	Rough	1,5	2	3	4,5	6
	Smooth	1	1,5	2	3	4
	Polished or slickenside *	0,5	1	1,5	2	3
For filled joint $j_R=1$. For irregular joint a rating of $j_R=5$ is suggested						
*) for slickenside surfaces the rating apply to possible movement along the lineations.						
Joint alteration factor (j_A)						
Contact between joint walls	Joint wall character		Condition		Wall contact	
	CLEAN JOINTS	Healed or welded joints	filling of quartz, epidote, etc.		0,75	
		Fresh joint walls	no coating or filling, except from staining (rust)		1	
		Altered joint walls	one grade higher alteration than the rock		2	
	two grades higher alteration than the rock		4			
	COATING or THIN FILLING	Friction materials	sand, silt calcite, etc. without content of clay		3	
Cohesive materials		clay, chlorite, talc, etc.		4		
Partly or no wall contact	Filling	Type		Party wall contact	No wall contact	
				thin filling (<5mm)	thick filling or gouge	
	Friction materials	sand, silt calcite, etc. (non softening)		4	8	
	Hard, cohesive materials	compacted filling of clay, chlorite, talc, etc.		6	6-10	
	Soft, cohesive materials	medium to low ever consolidated clay, chlorite, talc, etc.		8	12	
Swelling clay materials	filling material exhibits swelling properties		8-12	13-20		
Joint size factor (j_L)						
Type	Length	Size		Continuous joints	Discontin. Joints *	
Bedding or foliation partings	<0,5 m	Very short		3	6	
	0,1-1 m	short or small		2	4	
		medium		1	2	
		long or large		0,75	1,5	
(Filled) joint, seam or shear **	>30 m	very long or large		0,50	1	
*) Discontinuous joints end in massive rock				**) Often a singularity and should in these cases be treated separately		

3_Profilo tipici di scabrezza (rugosità)

Barton & Choubey, 1977



RILIEVO GEOSTRUTTURALE

Codice rilievo:	RS_06	Coordinate UTM-WGS 84 (33T)		Quota [m s.l.m.]
Rilevatore:	Fassone A.	325937 E	4738973 N	328
Data:	18/10/22	Azimut della parete rocciosa: N86		
Comune:	Vallo di Nera	Litologia: Scaglia Rossa		
Località:	Eremita	Note:		

PLANIMETRIA DI UBICAZIONE

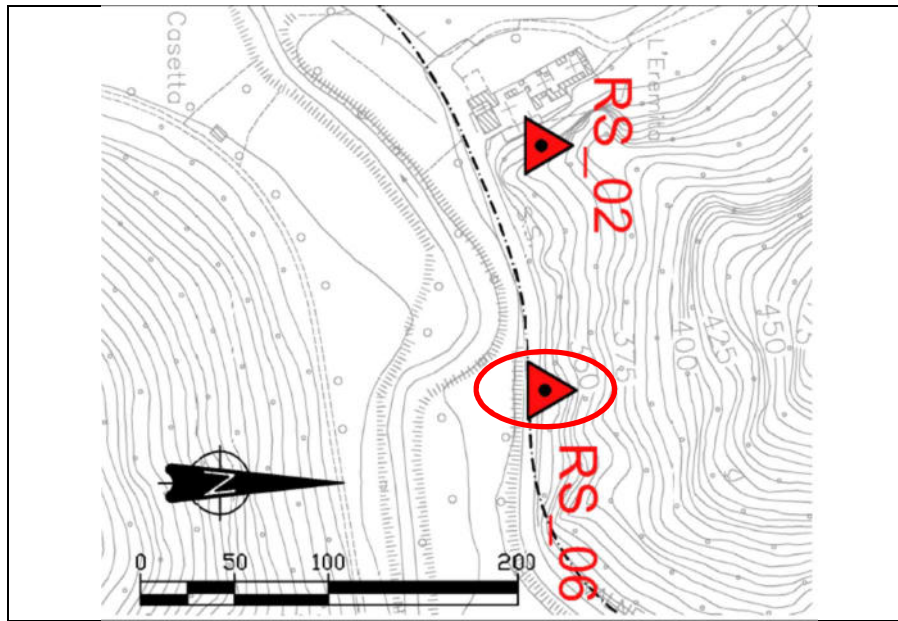


Fig.1. Carta di localizzazione del rilievo strutturale

DOCUMENTAZIONE FOTOGRAFICA

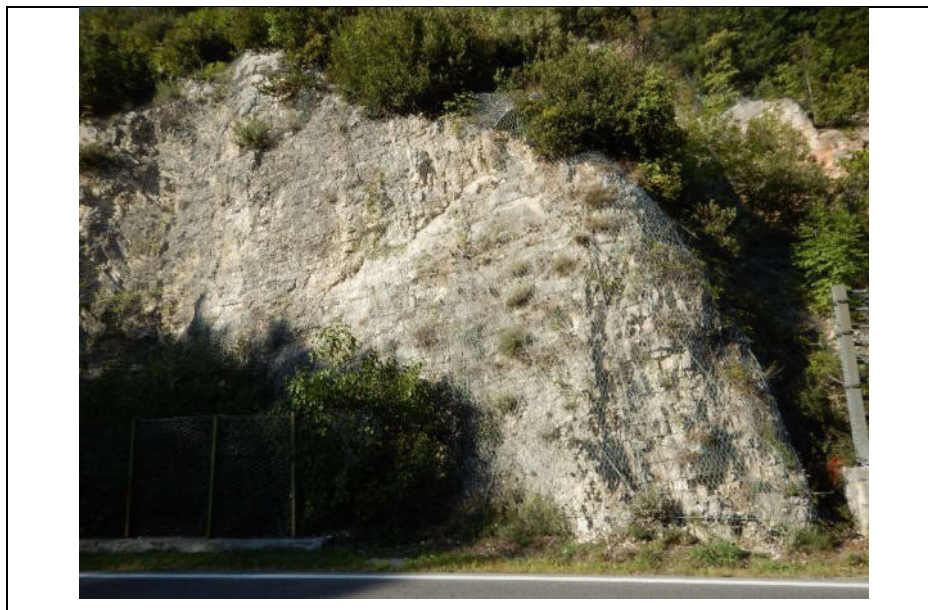


Fig.2. Vista d'insieme dell'affioramento

DESCRIZIONE DELL’AFFIORAMENTO

Affioramento roccioso: Scaglia Rossa (Turoniano inferiore - Eocene medio)
L’ammasso si presenta fratturato, contraddistinto da piani di stratificazione (St) ben evidenti e da tre famiglie di discontinuità principali (J1, J2, J3). Le fratture, generalmente aperte presentano superfici moderatamente alterate. L’affioramento si presenta privo di emergenze idriche.

Dimensione blocchi

Minima: 6 x 5 x 8 [cm]; **Massima:** 60 x 70 x 90 [cm]; **Frequente:** 20 x 30 x 15 [cm];

Spessore roccia affiorante: 8,00 – 12,00 m

Note:

CARATTERISTICHE GEOMECCANICHE DELLE DISCONTINUITA’
International Society for Rock Mechanics - ISRM (1981)
BGD (Basic Geotechnical Description)

Famiglia	Orientazione		Caratteristiche delle discontinuità							
	Imm.	Incl.	Spaziatura	Persistenza	Rugosità	Grado di alterazione	Apertura	Riempimento	Condizioni Idrauliche	JRC
St	320	10	S2 (S3)	P3 (P4)	R4	C3	A4 (A3)	-	Secco	8-10
J1	40	86	S2	P3	R4	C3	A4 (A3)	-	Secco	8-10
J2	210	90	S3 (S2)	P3 (P2)	R4	C3	A3	-	Secco	8-10
J3	180	88	S2	P3	R4	C3	A4	-	Secco	8-10

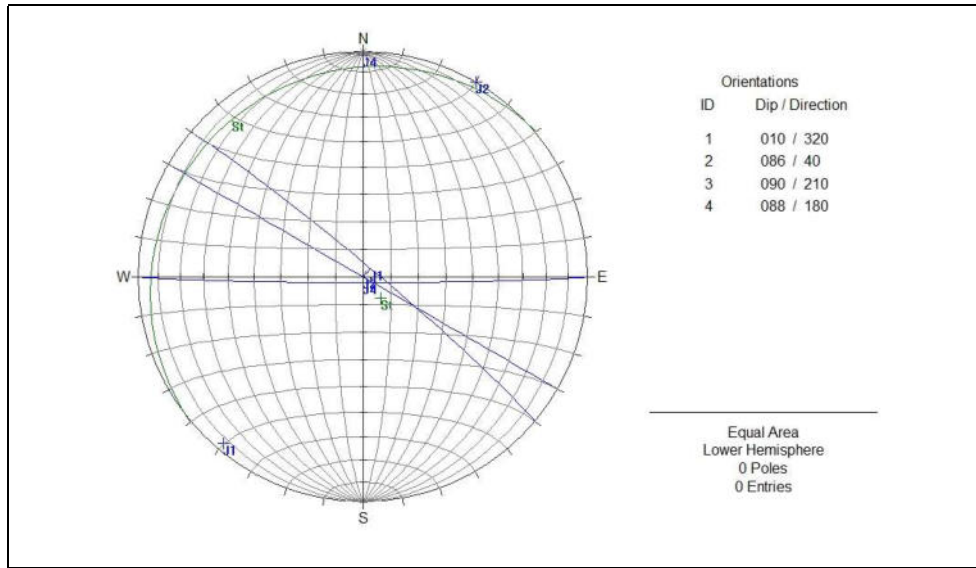
Note:

- St: Stratificazione; J: Giunto, frattura; F: Faglia, discontinuità tettonica.
- I termini tra parentesi descrivono caratteristiche subordinate.

CARATTERISTICHE GEOMECCANICHE DELLE DISCONTINUITA’
“Ratings” Evaluation – Métod PALMSTRØM (2000 – 2005)

Famiglia	Joint Condition <i>jC (Palmstrøm) = jR x jL / jA</i>		
	<i>jR</i>	<i>jL</i>	<i>JA</i>
St	2	0,75	2
J1	2	1	2
J2	2	2	2
J3	2	1	2

PROIEZIONE STEREOGRAFICA DELLE DISCONTINUITA'



VOLUME DEI BLOCCHI (V_b) E FATTORE DI FORMA DEL BLOCCO (β)
Palmstrøm (2005)

Volume dei blocchi (V_b) – misurati visivamente in sito [cm ³]				Fattore di forma del blocco	
Dimensione dei blocchi	Frequente	Min	Max	Palmstrøm, 2005	
				Extremely lung or flat blocks	Beta (β)
L1 [cm]	20	6	60	Very long or flat blocks	100 - 500
L2 [cm]	30	5	70	Moderately long or flat blocks	50 - 100
L3 [cm]	15	8	90	Slightly long or flat blocks	32 - 50
$V_b = L1 \times L2 \times L3$	9000	240	378000	Cubical blocks	27 - 32

VALUTAZIONE DEL GSI (GEOLOGICAL STRAIN INDEX)

Hoek and Marinos P. (2000) – Determinazione GSI per rocce fratturate

Marinos V. (2007) – Determinazione GSI per rocce flyschoidi

Russo (2007) – Determinazione GSI tramite i parametri RMI: jC e Vb. *

GEOLOGICAL STRENGTH INDEX FOR JOINTED ROCKS (Hoek and Marinos, 2000)		SURFACE CONDITIONS	
<p>From the lithology, structure and surface conditions of the discontinuities, estimate the average value of GSI. Do not try to be too precise. Quoting a range from 33 to 37 is more realistic than stating that GSI = 35. Note that the table does not apply to structurally controlled failures. Where weak planar structural planes are present in an unfavourable orientation with respect to the excavation face, these will dominate the rock mass behaviour. The shear strength of surfaces in rocks that are prone to deterioration as a result of changes in moisture content will be reduced if water is present. When working with rocks in the fair to very poor categories, a shift to the right may be made for wet conditions. Water pressure is dealt with by effective stress analysis.</p>		VERY GOOD Very rough, fresh unweathered surfaces	VERY POOR Stickensided, highly weathered surfaces with soft clay coatings or fillings
		GOOD Rough, slightly weathered, iron stained surfaces	VERY POOR Stickensided, highly weathered surfaces with compact coatings or fillings or angular fragments
STRUCTURE		FAIR Smooth, moderately weathered and altered surfaces	VERY POOR Stickensided, highly weathered surfaces with soft clay coatings or fillings
DECREASING INTERLOCKING OF ROCK PIECES		DECREASING SURFACE QUALITY →	
INTACT OR MASSIVE - intact rock specimens or massive in situ rock with few widely spaced discontinuities	90	N/A	N/A
BLOCKY - well interlocked undisturbed rock mass consisting of cubical blocks formed by three intersecting discontinuity sets	80		
VERY BLOCKY - interlocked, partially disturbed mass with multi-faceted angular blocks formed by 4 or more joint sets	70		
BLOCKY/DISTURBED/SEAMY - folded with angular blocks formed by many intersecting discontinuity sets. Persistence of bedding planes or schistosity	60		
DISINTEGRATED - poorly interlocked, heavily broken rock mass with mixture of angular and rounded rock pieces	50		
LAMINATED/SHEARED - Lack of blockiness due to close spacing of weak schistosity or shear planes	40		
	30		
	20		
	10		

GSI: 45 - 50

Determinazione del GSI (Hoek and Marinos P., 2000)

GEOLOGICAL STRENGTH INDEX (GSI) FOR HETEROGENEOUS ROCK MASSES SUCH AS FLYSCH (V. Marinos, 2007)		SURFACE CONDITIONS OF DISCONTINUITIES (Predominantly bedding planes)	
<p>Heterogeneous rockmasses are meant those with alternating layers of clearly different lithology types with significant differences in their strength properties. For flysch, a typical formation with heterogeneous rock masses, these alternations are consisting of sandstones and siltstones. Clay shales may be present. From a description of the lithology, structure and surface conditions of discontinuities (particularly of the bedding planes), choose a box in the chart. The selection of the structure should be based on the tectonic disturbance (undisturbed, slightly disturbed, strongly disturbed - folded, desintegrated, sheared), the proportion of siltstones against sandstones and the expressed or not stratification inside the siltstone layers. In the type IV and V when the thickness of sandstone beds exceed 50cm an increase of the GSI value by 5 is suggested. From type IV and the following types, the stratification planes are perceptible inside the siltstone mass. Locate the position in the box that corresponds to the conditions and estimate the average value GSI from the contours. The determination of the structure and the condition of discontinuities may range between two adjacent fields. Note that the Hoek - Brown criterion does not apply to structurally controlled failures. Where unfavourably oriented continuous weak planar discontinuities are present, these will dominate the behaviour of the rock mass. The strength of some rock masses is reduced by the presence of groundwater and this can be allowed for by a slight shift to the right in the columns for fair, poor and very poor conditions. Water pressure does not change the value of GSI and it is dealt with by using effective stress analysis.</p>		VERY GOOD Very rough, fresh unweathered surfaces	VERY POOR Very smooth, slickensided or highly weathered surfaces with soft clay coating or fillings
		GOOD Rough, slightly weathered or oxidised surfaces	VERY POOR Very smooth, slickensided or highly weathered surfaces with soft clay coating or fillings
STRUCTURE AND COMPOSITION		DECREASE OF THE QUALITY OF DISCONTINUITIES →	
TYPE I. Undisturbed, with thick to medium thickness sandstone beds with sporadic thin films of siltstone. In shallow tunnels or slopes where confinement is poor the mode of the failure has a kinematic character controlled by the bedding planes and GSI is meaningless	TYPE II. Undisturbed massive siltstone (stratification planes are imperceptible) with sporadic thin interlayers of sandstones	80	I II N/A N/A
TYPE III. Moderately disturbed sandstones with thin films of interlayers of siltstone	TYPE IV. Moderately disturbed rockmass with sandstone and siltstone similar amounts	70	III IV V VI N/A
TYPE V. Moderately disturbed siltstones with sandstone interlayers	TYPE VI. Moderately disturbed siltstones with sparse sandstone interlayers	60	III IV V VI N/A
TYPE VII. Strongly disturbed, folded rockmass that retains its structure, with sandstone and siltstone in similar extend	TYPE VIII. Strongly disturbed, folded rockmass, with siltstones and sandstone interlayers. The structure is retained and deformation - shearing is not strong	50	III IV V VI N/A
TYPE IX. Desintegrated rockmass that can be found in wide zones of faults or/and of high weathering. In this type mainly brittle material is present with some disturbed siltstones between rock pieces	TYPE X. Tectonically deformed intensively folded/ faulted siltstone or clay shale with broken and deformed sandstone layers forming an almost chaotic structure	40	VII VIII
TYPE XI. Tectonically strongly sheared siltstone or clayey shale forming a chaotic structure with pockets of clay. Thin layers of sandstone are transformed into small rock pieces. Ultimately the ground behavior is that of a soil		30	IX X XI
		20	IX X XI
		10	IX X XI

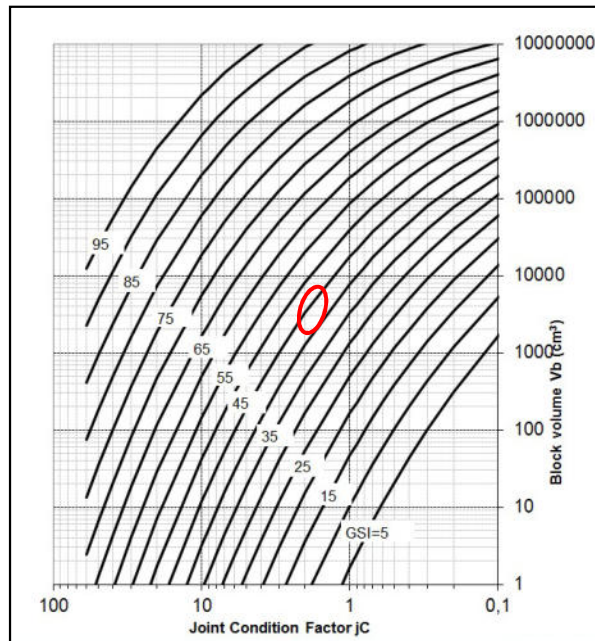
N/A Means geologically impossible combination. In the non - shadowed areas, such rockmasses are not impossible to find but it is very unusual

→ Direction of tectonic disturbance and deformation of equivalent rockmass lithology

GSI: xxx

Determinazione del GSI (Marinos V., 2007)

Relazione sui rilievi geologico strutturali di dettaglio



GSI: 40-50

Determinazione del GSI tramite i parametri RMI: jC e Vb. (Russo, 2007)

*RMI: Rock Mass index (Palmstrøm, 1994)

VALUTAZIONE DELLA RESISTENZA A COMPRESSIONE UNIASSIALE MEDIANTE SCLEROMETRO (Martello di Schmidt)
ISRM (1978a e 1978b); Miller (1965)

Famiglia	Direzione di applicazione	Indice di rimbalzo (Martello di Schmidt)											
		1	2	3	4	5	6	7	8	9	10	11	12
J1	↑	36	20	32	28	26	28	34	32	36	30	28	36
J3	→	50	52	42	50	50	46	26	28	32	44	46	36

APPENDICE

1_Caratteristiche geomeccaniche delle discontinuità Basic Geotechnical Description (ISRM, 1981)

Characteristics	Id	Typology	Range	
SPACING	S1	Very close spacing	< 6 cm	
	S2	Close spacing	6-20 cm	
	S3	Moderate spacing	20 - 60 cm	
	S4	Wide spacing	60 - 200 cm	
	S5	Very wide spacing	> 200 cm	
PERSISTENCE	P1	Very low persistence	< 1 m	
	P2	Low persistence	1 – 3 m	
	P3	Medium persistence	10 – 20 m	
	P4	High persistence	10 – 20 m	
	P5	Very high persistence	> 20m	
ROUGHNESS	Stepped	R1	Rough (or irregular)	-
		R2	Smooth	-
		R3	Slickenside	-
	Undulating	R4	Rough (or irregular)	-
		R5	Smooth	-
		R6	Slickenside	-
	Planar	R7	Rough (or irregular)	-
		R8	Smooth	-
		R9	Slickenside	-
JOINT CONDITIONS	C1	Fresh	-	
	C2	Slightly weathered	-	
	C3	Moderately weathered	-	
	C4	Highly weathered	-	
	C5	Completely weathered	-	
	C6	Residual soil	-	
APERTURE	A1	Closed	0.0 mm	
	A2	Very tight - Tight	< 0.1 mm	
	A3	Partly open - Open	0.1 mm – 1 mm	
	A4	Open - Moderately wide	1 mm – 5 mm	
	A5	Moderately wide - Wide	> 5mm	

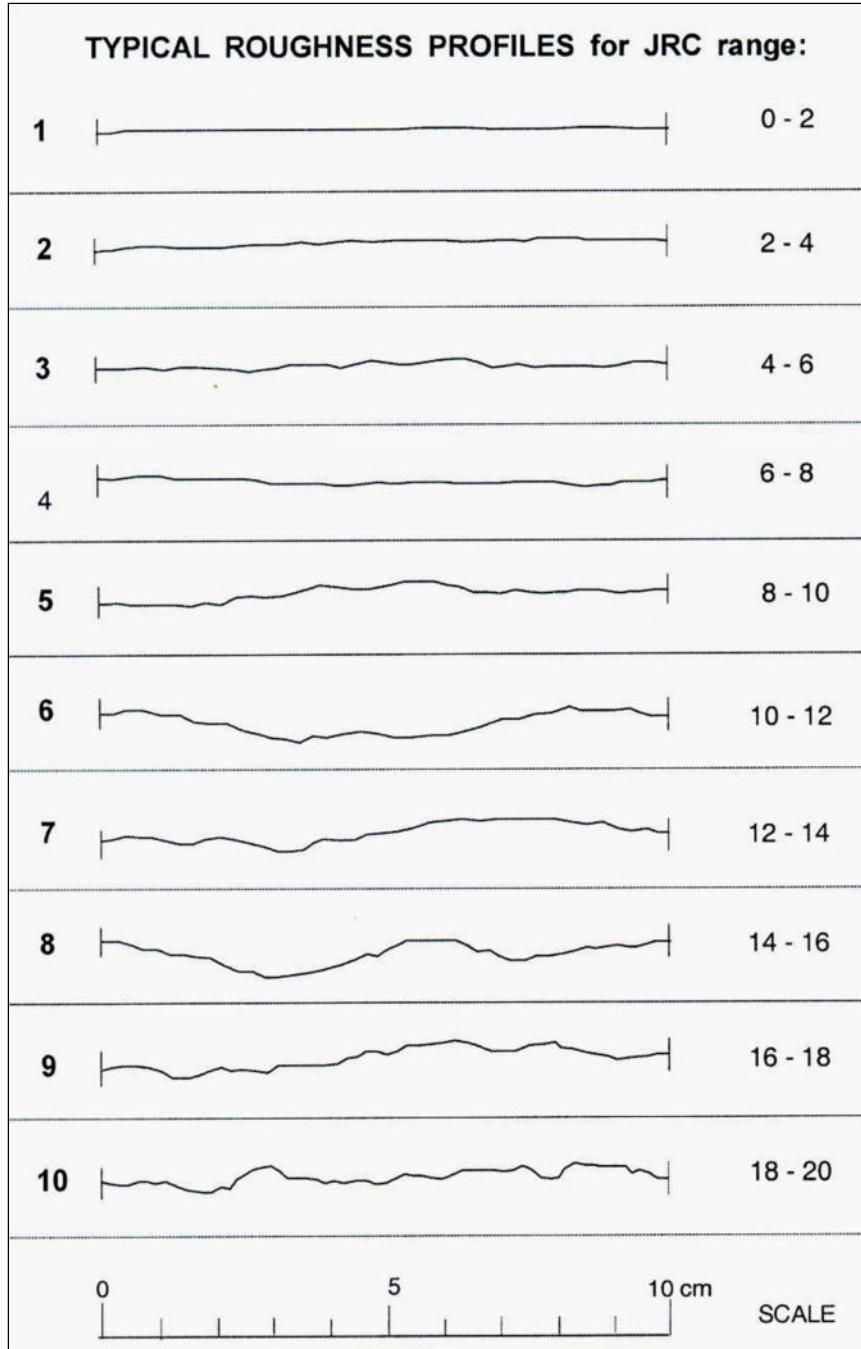
2_Caratteristiche geomeccaniche delle discontinuità

"Ratings" Evaluation – Métod PALMSTRØM (2000 – 2005)

"RATINGS" EVALUATION – MÉTODO PALMSTRØM (2000 - 2005)						
Joint Condition Factor j_C		$j_C \text{ (Palmstrøm)} = j_R \times j_L / j_A$				
Joint roughness factor (j_R)		Large scale waviness of joint plane				
		Planar	Slightly undulating	Undulating	Strongly undulating	Stepped or Interlocking
small scale smoothness of joint surface	Very rough	2	3	4	6	6
	Rough	1,5	2	3	4,5	6
	Smooth	1	1,5	2	3	4
	Polished or slickenside *	0,5	1	1,5	2	3
For filled joint $j_R=1$. For irregular joint a rating of $j_R=5$ is suggested						
*) for slickenside surfaces the rating apply to possible movement along the lineations.						
Joint alteration factor (j_A)						
Contact between joint walls	Joint wall character		Condition		Wall contact	
	CLEAN JOINTS	Healed or welded joints	filling of quartz, epidote, etc.		0,75	
		Fresh joint walls	no coating or filling, except from staining (rust)		1	
		Altered joint walls	one grade higher alteration than the rock		2	
	two grades higher alteration than the rock		4			
	COATING or THIN FILLING	Friction materials	sand, silt calcite, etc. without content of clay		3	
Cohesive materials		clay, chlorite, talc, etc.		4		
Partly or no wall contact	Filling	Type	Party wall contact	No wall contact		
			thin filling (<5mm)	thick filling or gouge		
	Friction materials	sand, silt calcite, etc. (non softening)	4	8		
	Hard, cohesive materials	compacted filling of clay, chlorite, talc, etc.	6	6-10		
	Soft, cohesive materials	medium to low ever consolidated clay, chlorite, talc, etc.	8	12		
Swelling clay materials	filling material exhibits swelling properties	8-12	13-20			
Joint size factor (j_L)						
Type	Length	Size	Continuous joints	Discontin. Joints *		
Bedding or foliation partings	<0,5 m	Very short	3	6		
	0,1-1 m	short or small	2	4		
		medium	1	2		
		long or large	0,75	1,5		
(Filled) joint, seam or shear **	>30 m	very long or large	0,50	1		
*) Discontinuous joints end in massive rock			**) Often a singularity and should in these cases be treated separately			

3_Profilo tipici di scabrezza (rugosità)

Barton & Choubey, 1977



RILIEVO GEOSTRUTTURALE

Codice rilievo:	RS_07	Coordinate UTM-WGS 84 (33T)		Quota [m s.l.m.]
Rilevatore:	Fassone A.	325700 E	4738828 N	324
Data:	19/10/22	Azimut della parete rocciosa: N35		
Comune:	Vallo di Nera	Litologia: Scaglia Rossa		
Località:	Eremita	Note:		

PLANIMETRIA DI UBICAZIONE

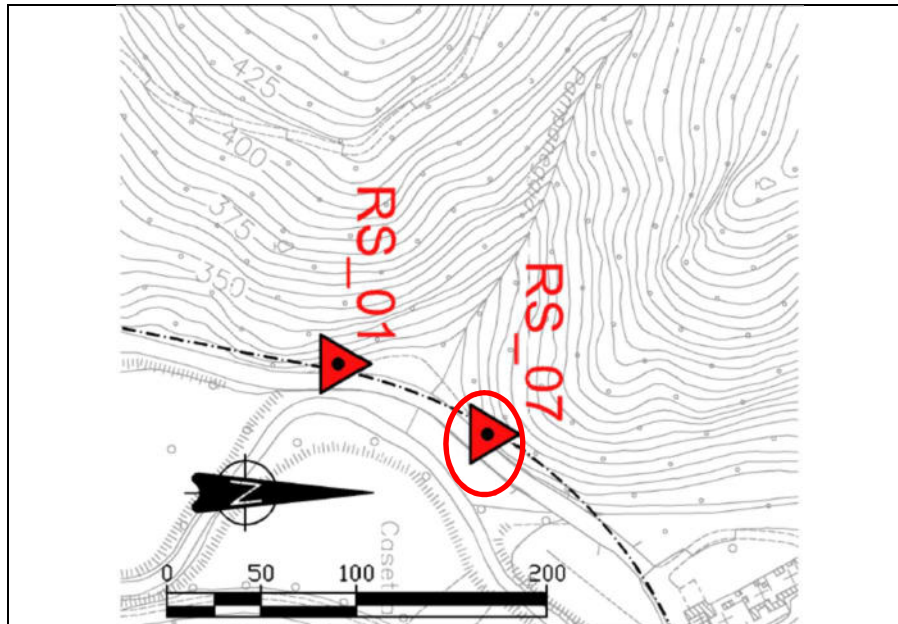


Fig.1. Carta di localizzazione del rilievo strutturale

DOCUMENTAZIONE FOTOGRAFICA



Fig.2. Vista d'insieme dell'affioramento

DESCRIZIONE DELL’AFFIORAMENTO

Affioramento roccioso: Scaglia Rossa (Turoniano inferiore - Eocene medio)
L’ammasso si presenta fratturato e contraddistinto da fratture lungo i piani di stratificazione (St=J1) e da quattro famiglie di discontinuità principali (F, J2, J3). Le fratture, generalmente aperte sono riempite da materiale residuale. L’affioramento si presenta privo di emergenze idriche.

Dimensione blocchi

Minima: 6 x 5 x 5 [cm]; **Massima:** 60 x 50 x 70 [cm]; **Frequente:** 20 x 15 x 25 [cm];

Spessore roccia affiorante: 4,00 – 6,00 m

Note: Settore deformato, caratterizzato dalla presenza di strutture tettoniche (faglie).

CARATTERISTICHE GEOMECCANICHE DELLE DISCONTINUITA’
International Society for Rock Mechanics - ISRM (1981)
BGD (Basic Geotechnical Description)

Famiglia	Orientazione		Caratteristiche delle discontinuità							
	Imm.	Incl.	Spaziatura	Persistenza	Rugosità	Grado di alterazione	Apertura	Riempimento	Condizioni Idrauliche	JRC
St=J1	260	82	S2 (S3)	P3 (P4)	R4	C3	A4 (A5)	-	secco	8-10
F	248	62	S5	P3 (P4)	R4 (R5)	C4	A5	F6	secco	6-8
J2	330	82	S2 (S3)	P2 (P3)	R4	C3	A2	-	secco	8-10
J3	180	60	S2 (s2)	P2 (P3)	R4	C3	A2	-	secco	8-10

Note:

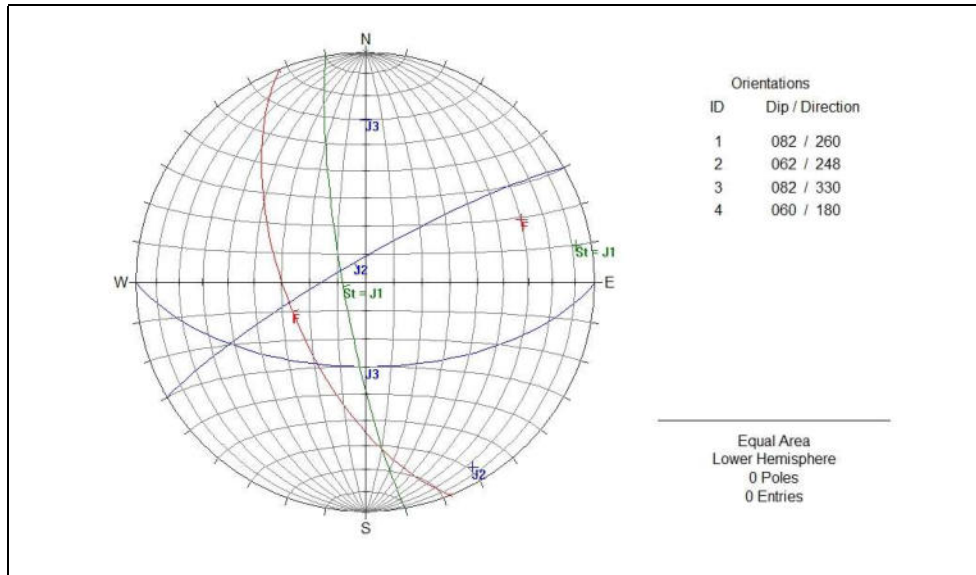
- St: Stratificazione; J: Giunto, frattura; F: Faglia, discontinuità tettonica.
- I termini tra parentesi descrivono caratteristiche subordinate.

CARATTERISTICHE GEOMECCANICHE DELLE DISCONTINUITA’
"Ratings" Evaluation – Métod PALMSTRØM (2000 – 2005)

Famiglia	Joint Condition jC (Palmstrøm) = jR x jL /jA		
	jR	jL	JA
St = J1	2	0,75	3
F	1	0,75	4
J2	2	2	2
J3	2	2	2

Relazione sui rilievi geologico strutturali di dettaglio

PROIEZIONE STEREOGRAFICA DELLE DISCONTINUITA'



VOLUME DEI BLOCCHI (V_b) E FATTORE DI FORMA DEL BLOCCO (β)
Palmstrøm (2005)

Volume dei blocchi (V_b) – misurati visivamente in sito [cm ³]				Fattore di forma del blocco	
Dimensione dei blocchi	Frequente	Min	Max	Palmstrøm, 2005	Beta (β)
				Extremely lung or flat blocks	>500
L1 [cm]	20	6	60	Very long or flat blocks	100 - 500
L2 [cm]	15	5	50	Moderately long or flat blocks	50 - 100
L3 [cm]	25	5	70	Slightly long or flat blocks	32 - 50
$V_b = L1 \times L2 \times L3$	7500	150	13000	Cubical blocks	27 - 32

VALUTAZIONE DEL GSI (GEOLOGICAL STRAIN INDEX)

Hoek and Marinos P. (2000) – Determinazione GSI per rocce fratturate

Marinos V. (2007) – Determinazione GSI per rocce flyschoidi

Russo (2007) – Determinazione GSI tramite i parametri RMI: jC e Vb. *

GEOLOGICAL STRENGTH INDEX FOR JOINTED ROCKS (Hoek and Marinos, 2000)

From the lithology, structure and surface conditions of the discontinuities, estimate the average value of GSI. Do not try to be too precise. Quoting a range from 33 to 37 is more realistic than stating that GSI = 35. Note that the table does not apply to structurally controlled failures. Where weak planar structural planes are present in an unfavourable orientation with respect to the excavation face, these will dominate the rock mass behaviour. The shear strength of surfaces in rocks that are prone to deterioration as a result of changes in moisture content will be reduced if water is present. When working with rocks in the fair to very poor categories, a shift to the right may be made for wet conditions. Water pressure is dealt with by effective stress analysis.

SURFACE CONDITIONS	DECREASING SURFACE QUALITY →			
	VERY GOOD Very rough, fresh unweathered surfaces	GOOD Rough, slightly weathered, iron stained surfaces	FAIR Smooth, moderately weathered and altered surfaces	POOR Stickensided, highly weathered surfaces with compact coatings or fillings or angular fragments
STRUCTURE	DECREASING INTERLOCKING OF ROCK PIECES ↓			
INTACT OR MASSIVE - intact rock specimens or massive in situ rock with few widely spaced discontinuities	90			N/A
BLOCKY - well interlocked undisturbed rock mass consisting of cubical blocks formed by three intersecting discontinuity sets	80	70		
VERY BLOCKY - interlocked, partially disturbed mass with multi-faceted angular blocks formed by 4 or more joint sets		60	50	
BLOCKY/DISTURBED/SEAMY - folded with angular blocks formed by many intersecting discontinuity sets. Persistence of bedding planes or schistosity			40	
DISINTEGRATED - poorly interlocked, heavily broken rock mass with mixture of angular and rounded rock pieces				20
LAMINATED/SHEARED - Lack of blockiness due to close spacing of weak schistosity or shear planes	N/A	N/A		10

VERY GOOD
Very rough, fresh unweathered surfaces

GOOD
Rough, slightly weathered, iron stained surfaces

FAIR
Smooth, moderately weathered and altered surfaces

POOR
Stickensided, highly weathered surfaces with compact coatings or fillings or angular fragments

VERY POOR
Stickensided, highly weathered surfaces with soft clay coatings or fillings

GSI: 30 - 35

Determinazione del GSI (Hoek and Marinos P., 2000)

GEOLOGICAL STRENGTH INDEX (GSI) FOR HETEROGENEOUS ROCK MASSES SUCH AS FLYSCH (V. Marinos, 2007)

Heterogeneous rockmasses are meant those with alternating layers of clearly different lithology types with significant differences in their strength properties. For flysch, a typical formation with heterogeneous rock masses, these alternations are consisting of sandstones and siltstones. Clay shales may be present. From a description of the lithology, structure and surface conditions of discontinuities (particularly of the bedding planes), choose a box in the chart. The selection of the structure should be based on the tectonic disturbance (undisturbed, slightly disturbed, strongly disturbed - folded, desintegrated, sheared), the proportion of siltstones against sandstones and the expressed or not stratification inside the siltstone layers. In the type IV and V when the thickness of sandstone beds exceed 50cm an increase of the GSI value by 5 is suggested. From type IV and the following types, the stratification planes are perceptible inside the siltstone mass. Locate the position in the box that corresponds to the conditions and estimate the average value GSI from the contours. The determination of the structure and the condition of discontinuities may range between two adjacent fields. Note that the Hoek - Brown criterion does not apply to structurally controlled failures. Where unfavourably oriented continuous weak planar discontinuities are present, these will dominate the behaviour of the rock mass. The strength of some rock masses is reduced by the presence of groundwater and this can be allowed for by a slight shift to the right in the columns for fair, poor and very poor conditions. Water pressure does not change the value of GSI and it is dealt with by using effective stress analysis.

STRUCTURE AND COMPOSITION	DECREASE OF THE QUALITY OF DISCONTINUITIES →			
	VERY GOOD Very rough, fresh unweathered surfaces	GOOD Rough, slightly weathered or oxidised surfaces	FAIR Smooth, moderately weathered and altered surfaces	POOR Very smooth, occasionally stickensided surfaces with compact coatings or fillings with angular fragments
TYPE I. Undisturbed, with thick to medium thickness sandstone beds with sporadic thin films of siltstone. In shallow tunnels or slopes where confinement is poor the mode of the failure has a kinematic character controlled by the bedding planes and GSI is meaningless	80	I	II	N/A
TYPE II. Undisturbed massive siltstone (stratification planes are imperceptible) with sporadic thin interlayers of sandstones				N/A
TYPE III. Moderately disturbed sandstones with thin films of interlayers of siltstone	60	III	IV	V
TYPE IV. Moderately disturbed rockmass with sandstone and siltstone similar amounts				N/A
TYPE V. Moderately disturbed siltstones with sandstone interlayers				N/A
TYPE VI. Moderately disturbed siltstones with sparse sandstone interlayers				N/A
TYPE VII. Strongly disturbed, folded rockmass that retains its structure, with sandstone and siltstone in similar extend	N/A		VII	VIII
TYPE VIII. Strongly disturbed, folded rockmass, with siltstones and sandstone interlayers. The structure is retained and deformation - shearing is not strong				
TYPE IX. Desintegrated rockmass that can be found in wide zones of faults or/and of high weathering. In this type mainly brittle material is present with some disturbed siltstones between rock pieces	N/A		IX	X
TYPE X. Tectonically deformed intensively folded/ faulted siltstone or clay shale with broken and deformed sandstone layers forming an almost chaotic structure				
TYPE XI. Tectonically strongly sheared siltstone or clayey shale forming a chaotic structure with pockets of clay. Thin layers of sandstone are transformed into small rock pieces. Ultimately the ground behavior is that of a soil	N/A	N/A		XI

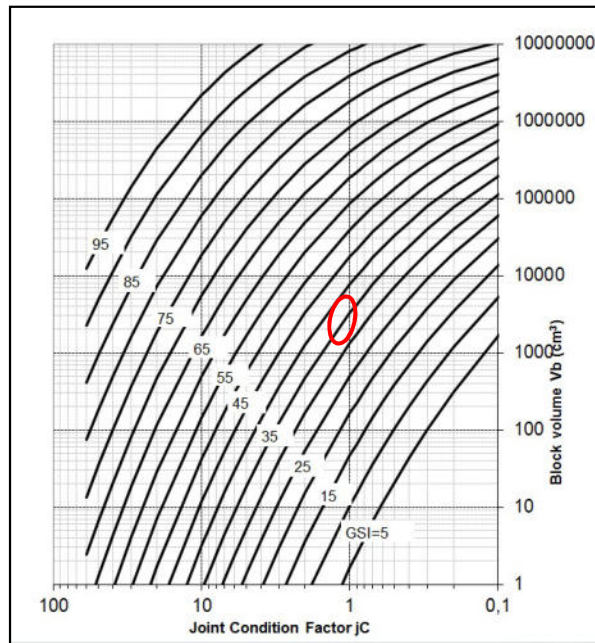
N/A Means geologically impossible combination. In the non - shadowed areas, such rockmasses are not impossible to find but it is very unusual

→ Direction of tectonic disturbance and deformation of equivalent rockmass lithology

GSI: xxx

Determinazione del GSI (Marinos V., 2007)

Relazione sui rilievi geologico strutturali di dettaglio



GSI: 30-40

Determinazione del GSI tramite i parametri RMI: jC e Vb. (Russo, 2007)

*RMI: Rock Mass index (Palmstrøm, 1994)

VALUTAZIONE DELLA RESISTENZA A COMPRESIONE UNIASSIALE MEDIANTE SCLEROMETRO (Martello di Schmidt)
ISRM (1978a e 1978b); Miller (1965)

Famiglia	Direzione di applicazione	Indice di rimbalzo (Martello di Schmidt)											
		1	2	3	4	5	6	7	8	9	10	11	12
St=J1	→	42	46	48	20	38	30	20	22	42	26	22	26
J2	←	24	28	30	20	30	28	40	44	36	20	40	25
J3	↘	42	42	48	42	24	44	46	42	30	36	26	42

APPENDICE

1_Caratteristiche geomeccaniche delle discontinuità Basic Geotechnical Description (ISRM, 1981)

Characteristics	Id	Typology	Range	
SPACING	S1	Very close spacing	< 6 cm	
	S2	Close spacing	6-20 cm	
	S3	Moderate spacing	20 - 60 cm	
	S4	Wide spacing	60 - 200 cm	
	S5	Very wide spacing	> 200 cm	
PERSISTENCE	P1	Very low persistence	< 1 m	
	P2	Low persistence	1 – 3 m	
	P3	Medium persistence	10 – 20 m	
	P4	High persistence	10 – 20 m	
	P5	Very high persistence	> 20m	
ROUGHNESS	Stepped	R1	Rough (or irregular)	-
		R2	Smooth	-
		R3	Slickenside	-
	Undulating	R4	Rough (or irregular)	-
		R5	Smooth	-
		R6	Slickenside	-
	Planar	R7	Rough (or irregular)	-
		R8	Smooth	-
		R9	Slickenside	-
JOINT CONDITIONS	C1	Fresh	-	
	C2	Slightly weathered	-	
	C3	Moderately weathered	-	
	C4	Highly weathered	-	
	C5	Completely weathered	-	
	C6	Residual soil	-	
APERTURE	A1	Closed	0.0 mm	
	A2	Very tight - Tight	< 0.1 mm	
	A3	Partly open - Open	0.1 mm – 1 mm	
	A4	Open - Moderately wide	1 mm – 5 mm	
	A5	Moderately wide - Wide	> 5mm	

2_Caratteristiche geomeccaniche delle discontinuità

"Ratings" Evaluation – Métod PALMSTRØM (2000 – 2005)

"RATINGS" EVALUATION – MÉTODO PALMSTRØM (2000 - 2005)						
Joint Condition Factor j_C		$j_C \text{ (Palmstrøm)} = j_R \times j_L / j_A$				
Joint roughness factor (j_R)		Large scale waviness of joint plane				
		Planar	Slightly undulating	Undulating	Strongly undulating	Stepped or Interlocking
small scale smoothness of joint surface	Very rough	2	3	4	6	6
	Rough	1,5	2	3	4,5	6
	Smooth	1	1,5	2	3	4
	Polished or slickenside *	0,5	1	1,5	2	3
For filled joint $j_R=1$. For irregular joint a rating of $j_R=5$ is suggested						
*) for slickenside surfaces the rating apply to possible movement along the lineations.						
Joint alteration factor (j_A)						
Contact between joint walls	Joint wall character		Condition		Wall contact	
	CLEAN JOINTS	Healed or welded joints	filling of quartz, epidote, etc.		0,75	
		Fresh joint walls	no coating or filling, except from staining (rust)		1	
		Altered joint walls	one grade higher alteration than the rock		2	
	two grades higher alteration than the rock		4			
	COATING or THIN FILLING	Friction materials	sand, silt calcite, etc. without content of clay		3	
Cohesive materials		clay, chlorite, talc, etc.		4		
Partly or no wall contact	Filling	Type	Party wall contact	No wall contact		
			thin filling (<5mm)	thick filling or gouge		
	Friction materials	sand, silt calcite, etc. (non softening)	4	8		
	Hard, cohesive materials	compacted filling of clay, chlorite, talc, etc.	6	6-10		
	Soft, cohesive materials	medium to low ever consolidated clay, chlorite, talc, etc.	8	12		
Swelling clay materials	filling material exhibits swelling properties	8-12	13-20			
Joint size factor (j_L)						
Type	Length	Size	Continuous joints	Discontin. Joints *		
Bedding or foliation partings	<0,5 m	Very short	3	6		
	0,1-1 m	short or small	2	4		
		medium	1	2		
		long or large	0,75	1,5		
(Filled) joint, seam or shear **	>30 m	very long or large	0,50	1		
*) Discontinuous joints end in massive rock			**) Often a singularity and should in these cases be treated separately			

3_Profilo tipici di scabrezza (rugosità)

Barton & Choubey, 1977

