

**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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R.T.P. :



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**STUDI E INDAGINI**

**Geologia**

**Relazione sui rilievi geologico strutturali di dettaglio**

CODICE PROGETTO

PROGETTO

PG0375 D 2301

NOME FILE

T00-GE00-GE0-RE02-A

CODICE ELAB.

T00GE00GEORE02

REVISIONE

SCALA

A

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A

EMISSIONE

Ottobre 2023

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REV.

DESCRIZIONE

DATA

REDATTO

VERIFICATO

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.

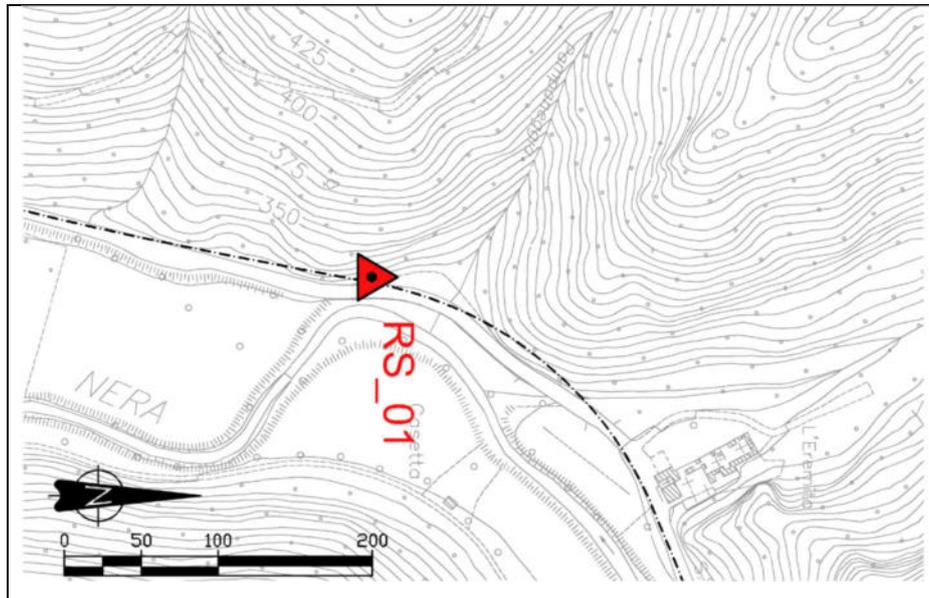
### **3 RILIEVI GEOSTRUTTURALI**

Di seguito sono riportate le schede dei rilievi geostrutturali eseguiti.

## RILIEVO GEOSTRUTTURALE

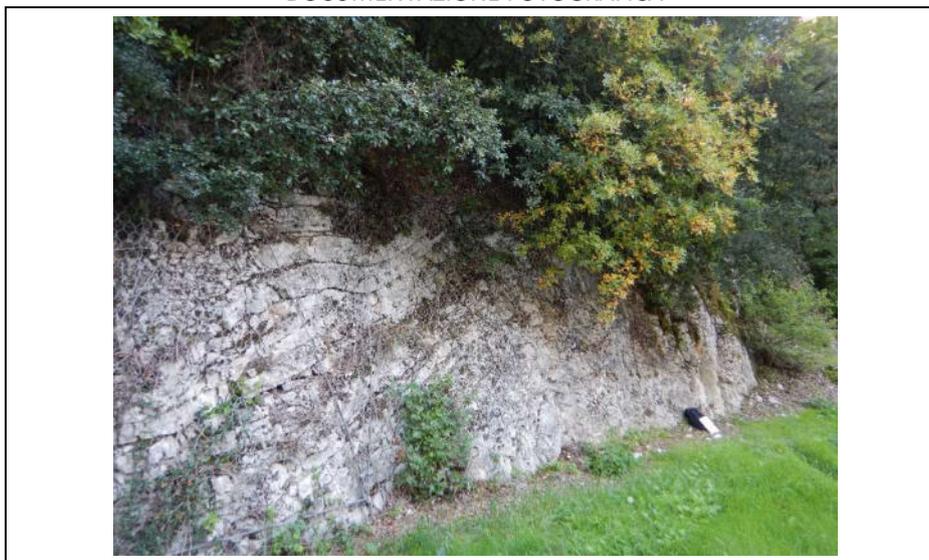
| Codice rilievo: | RS_01         | Coordinate UTM-WGS 84 (33T)        |           | Quota<br>[m s.l.m.] |
|-----------------|---------------|------------------------------------|-----------|---------------------|
| Rilevatore:     | Fassone A.    | 325665 E                           | 4738758 N | 324                 |
| 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:

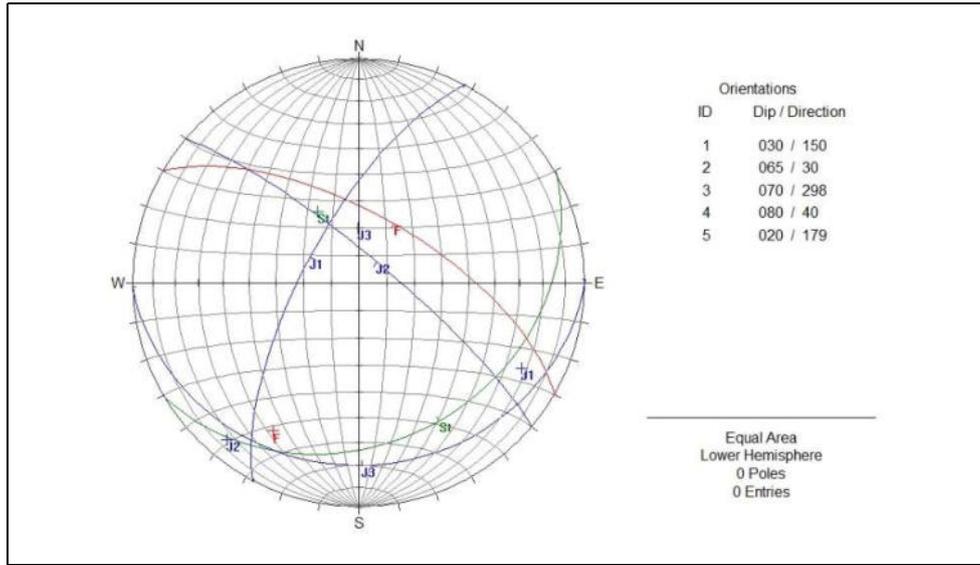
- St: Stratificazione; J: Giunto, frattura; F: Faglia, discontinuità tettonica.
- I termini tra parentesi descrivono caratteristiche subordinate.

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 ( $\beta$ )  
*Palmstrøm (2005)*

| Volume dei blocchi ( $V_b$ ) – misurati visivamente in sito [cm <sup>3</sup> ] |           |     |       | Fattore di forma del blocco    |                  |
|--|-----------|-----|-------|--------------------------------|------------------|
| Dimensione dei blocchi   | Frequente | Min | Max   | Palmstrøm, 2005                | Beta ( $\beta$ ) |
|  |           |     |       | 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   | <b>32 - 50</b>   |
| <b><math>V_b = L1 \times L2 \times L3</math></b>                               | 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)   |     | 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<br>Very rough, fresh unweathered surfaces      | VERY POOR<br>Slickensided, highly weathered surfaces with soft clay coatings or fillings |
|  |     | GOOD<br>Rough, slightly weathered, iron stained surfaces | VERY POOR<br>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>  | 70  |  |  |
|  <p>VERY BLOCKY - interlocked, partially disturbed mass with multi-faceted angular blocks formed by 4 or more joint sets</p>  | 50  |  |  |
|  <p>BLOCKY/DISTURBED/SEAMY - folded with angular blocks formed by many intersecting discontinuity sets. Persistence of bedding planes or schistosity</p>   | 40  |  |  |
|  <p>DISINTEGRATED - poorly interlocked, heavily broken rock mass with mixture of angular and rounded rock pieces</p>  | 30  |  |  |
|  <p>LAMINATED/SHEARED - Lack of blockiness due to close spacing of weak schistosity or shear planes</p>   | N/A | N/A  | 10   |

GSI: 35 - 40

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

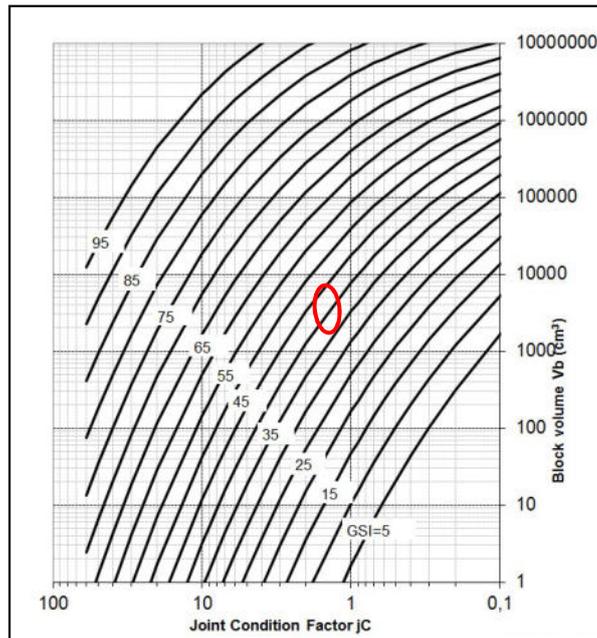
| GEOLOGICAL STRENGTH INDEX (GSI) FOR HETEROGENEOUS ROCK MASSES SUCH AS FLYSCH (V. Marinos, 2007)   |     | SURFACE CONDITIONS OF DISCONTINUITIES (Predominantly bedding planes) |  |
|---|-----|--|--|
| <p>Heterogeneous rockmasses are meant those with alternating layers of clearly different lithology 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<br>Very rough, fresh unweathered surfaces                  | VERY POOR<br>Very smooth, slickensided or highly weathered surfaces with soft clay coating or fillings |
|   |     | GOOD<br>Rough, slightly weathered or oxidised surfaces               | VERY POOR<br>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   |
|  <p>TYPE II. Undisturbed massive siltstone (stratification planes are imperceptible) with sporadic thin interlayers of sandstones</p>  | 70  | N/A  | N/A  |
|  <p>TYPE III. Moderately disturbed sandstones with thin films of interlayers of siltstone</p>  | 60  | III  | IV   |
|  <p>TYPE IV. Moderately disturbed rockmass with sandstone and siltstone similar amounts</p>   | 50  | V  | VI   |
|  <p>TYPE V. Moderately disturbed siltstones with sandstone interlayers</p>   | 40  | VII  | VIII   |
|  <p>TYPE VI. Moderately disturbed siltstones with sparse sandstone interlayers</p>   | 30  | IX   | X  |
|  <p>TYPE VII. Strongly disturbed, folded rockmass that retains its structure, with sandstone and siltstone in similar extend</p>   | N/A | N/A  | 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  | 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  | 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  | 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 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)



**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                |   |

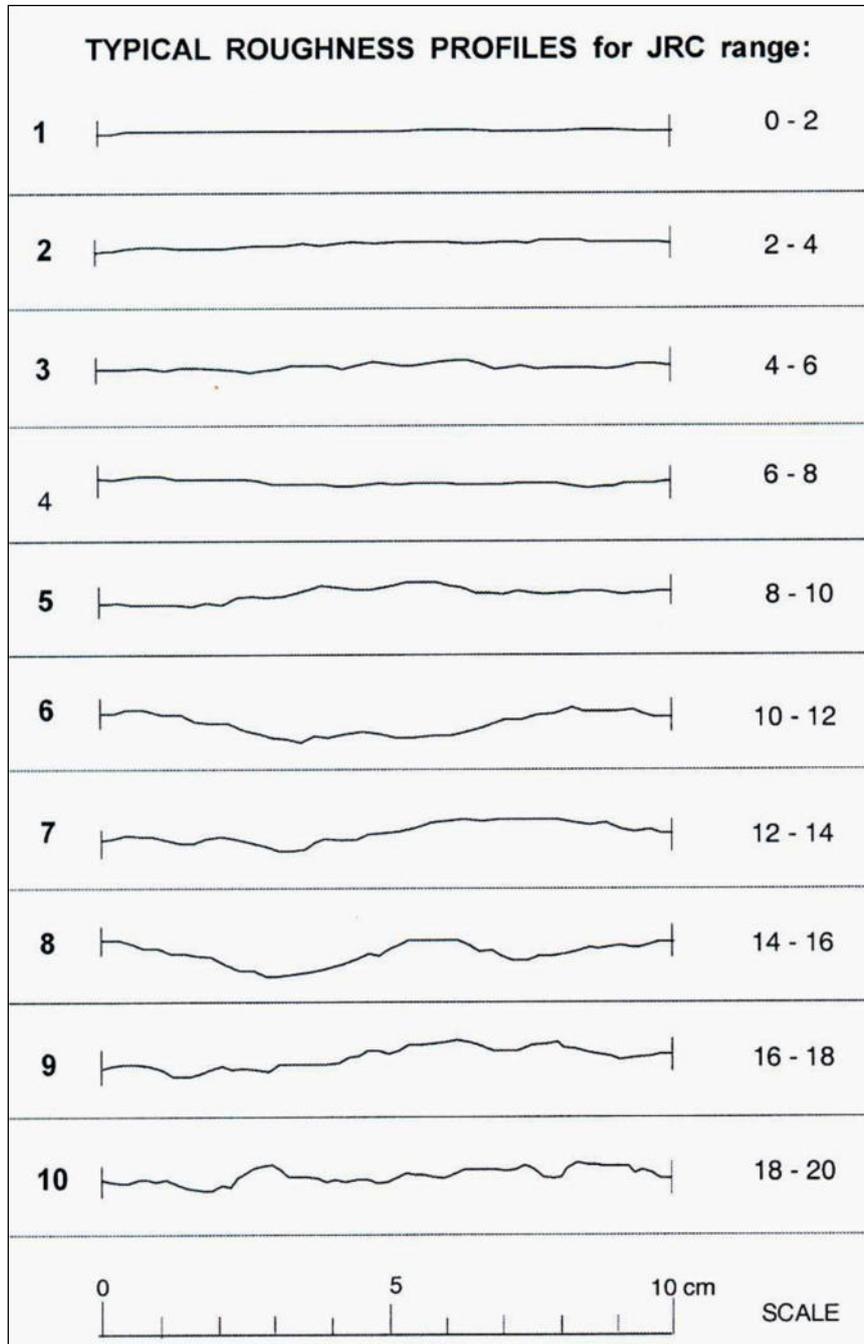
## 2\_Caratteristiche geomeccaniche delle discontinuità

"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\_Profilo tipici di scabrezza (rugosità)

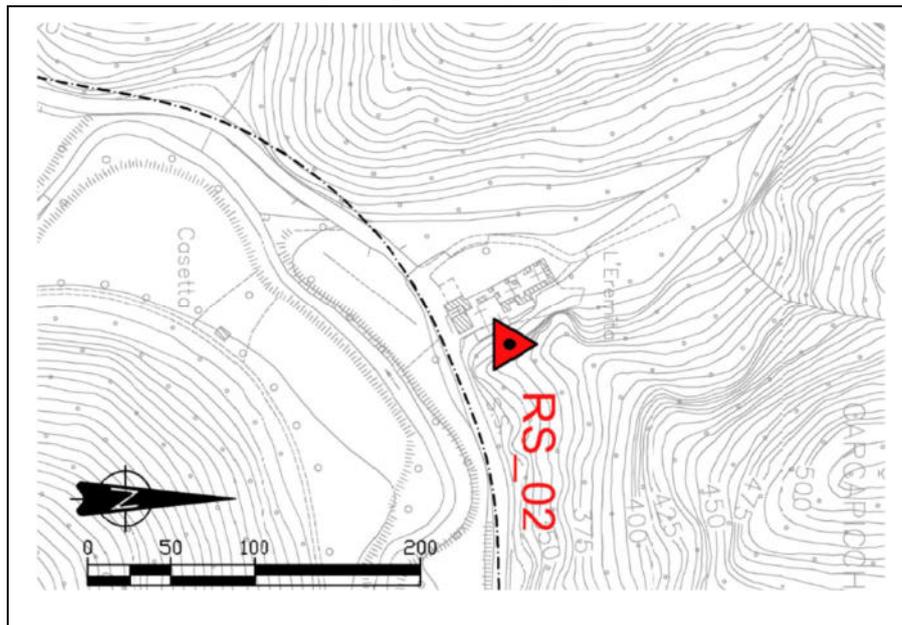
*Barton & Choubey, 1977*



### RILIEVO GEOSTRUTTURALE

| Codice rilievo: | RS_02            | Coordinate UTM-WGS 84 (33T)        |          | Quota<br>[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 |

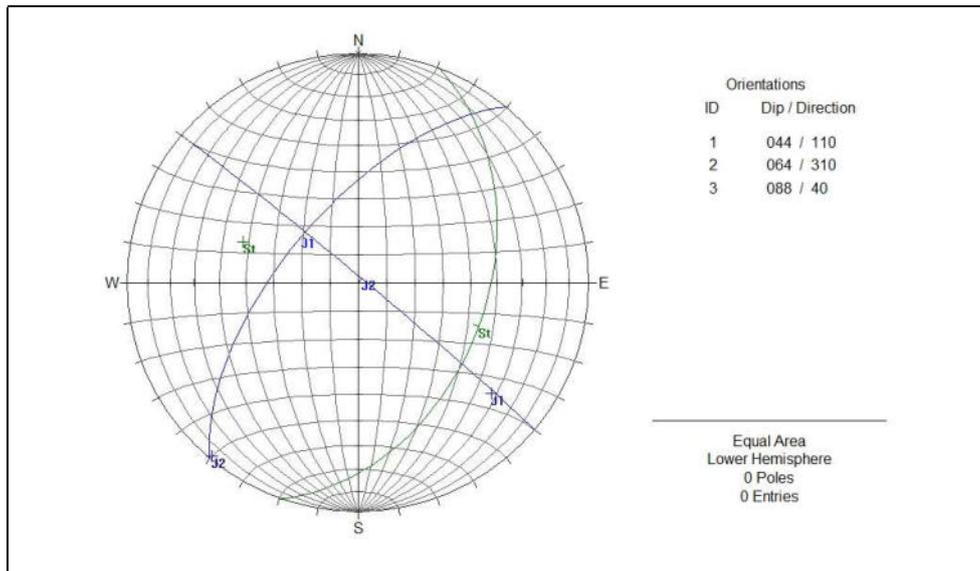
Note:

- 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'

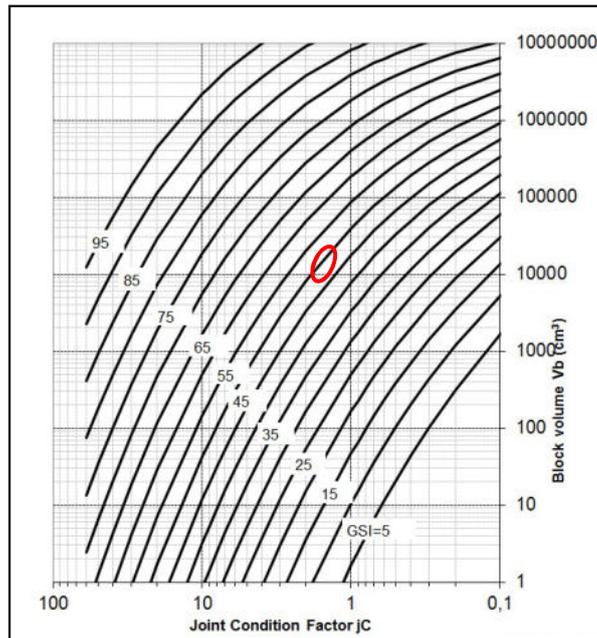


VOLUME DEI BLOCCHI ( $V_b$ ) E FATTORE DI FORMA DEL BLOCCO ( $\beta$ )  
*Palmstrøm (2005)*

| Volume dei blocchi ( $V_b$ ) – misurati visivamente in sito [cm <sup>3</sup> ] |           |      |        | Fattore di forma del blocco    |                  |
|--|-----------|------|--------|--------------------------------|------------------|
| Dimensione dei blocchi   | Frequente | Min  | Max    | Palmstrøm, 2005                | Beta ( $\beta$ ) |
|  |           |      |        | 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   | <b>32 - 50</b>   |
| <b><math>V_b = L1 \times L2 \times L3</math></b>                               | 28000     | 1200 | 105000 | Cubical blocks                 | 27 - 32          |



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 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       |  | 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                |   |

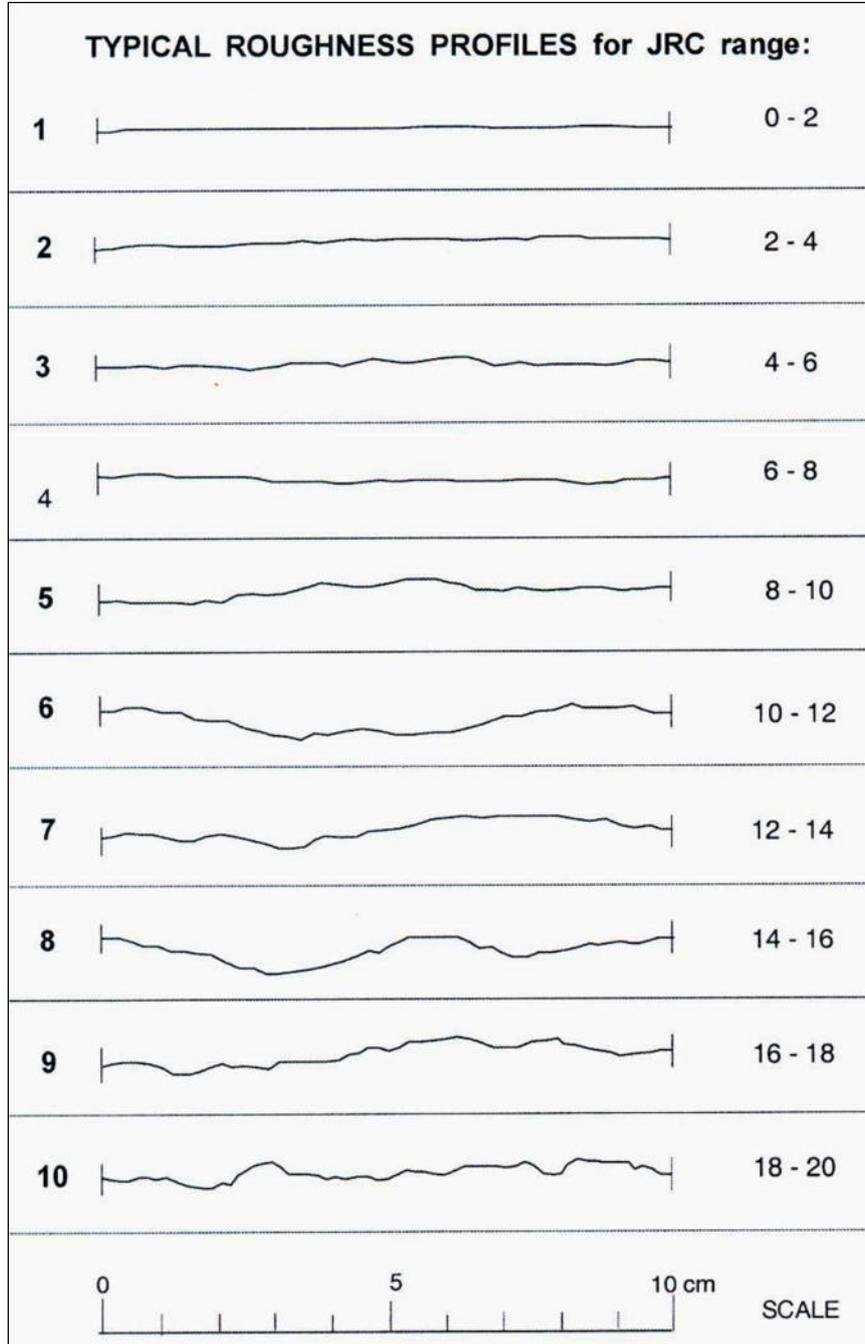
## 2\_Caratteristiche geomeccaniche delle discontinuità

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

| "RATINGS" EVALUATION – MÉTODO PALMSTRØM (2000 - 2005)   |   |  |   |                     |                        |                         |
|---|---|--|---|---------------------|------------------------|-------------------------|
| Joint Condition Factor $j_C$  |   | $j_C \text{ (Palmstrøm)} = j_R \times j_L / j_A$           |   |                     |                        |                         |
| 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 <u>lineations</u> . |   |  |   |                     |                        |                         |
| 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                      |                         |
|   | 0,1-1 m                                       | short or small   |   | 2                   | 4                      |                         |
|   |   | medium   |   | 1                   | 2                      |                         |
| Joints  | 1-10 m  | long or large  |   | 0,75                | 1,5                    |                         |
|   | 10-30 m                                       | very long or large   |   | 0,50                | 1                      |                         |
| (Filled) joint, seam or shear **  | >30 m   |  |   |                     |                        |                         |
| *) 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*



Relazione sui rilievi geologico strutturali di dettaglio

**RILIEVO GEOSTRUTTURALE**

| Codice rilievo: | RS_03         | Coordinate UTM-WGS 84 (33T)   |           | Quota<br>[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

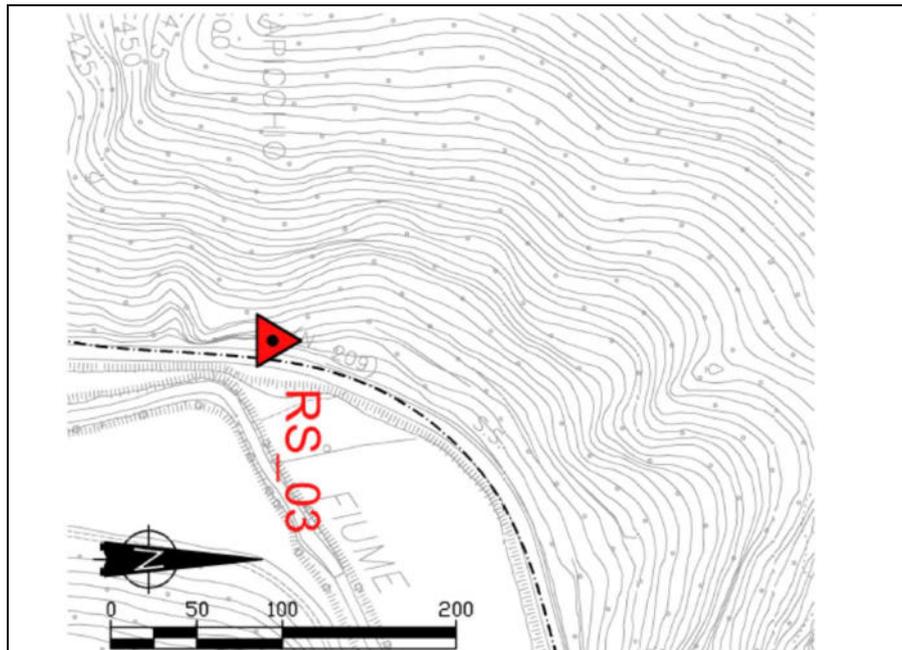


Fig.1. Carta di localizzazione del rilievo strutturale

DOCUMENTAZIONE FOTOGRAFICA

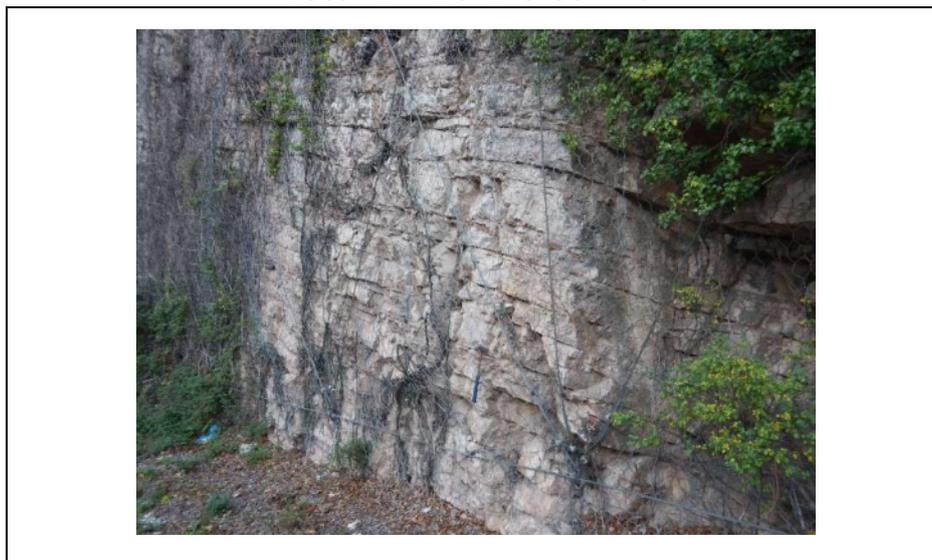


Fig.2. Vista d'insieme dell'affioramento

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 |
|          |              |       |                                     |             |          |                      |          |             |                       |      |
|          |              |       |                                     |             |          |                      |          |             |                       |      |

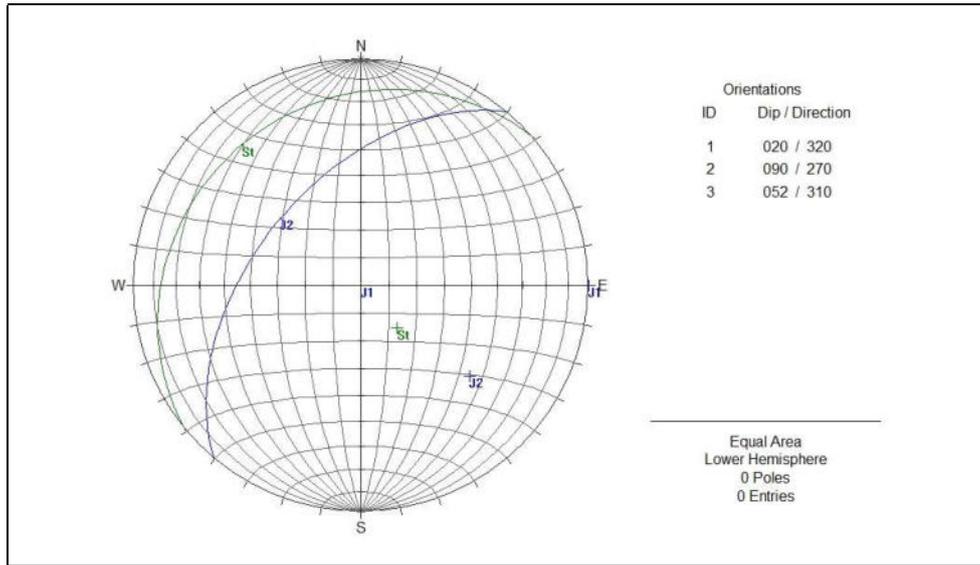
Note:

- 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 ( $\beta$ )  
*Palmstrøm (2005)*

| Volume dei blocchi ( $V_b$ ) – misurati visivamente in sito [cm <sup>3</sup> ] |           |     |       | Fattore di forma del blocco    |                  |
|--|-----------|-----|-------|--------------------------------|------------------|
| Dimensione dei blocchi   | Frequente | Min | Max   | Palmstrøm, 2005                |                  |
|  |           |     |       | Extremely lung or flat blocks  | Beta ( $\beta$ ) |
| 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   | <b>32 - 50</b>   |
| <b><math>V_b = L1 \times L2 \times L3</math></b>                               | 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<br>Very rough, fresh unweathered surfaces      | VERY POOR<br>Slickensided, highly weathered surfaces with soft clay coatings or fillings |
|  |    | GOOD<br>Rough, slightly weathered, iron stained surfaces | VERY POOR<br>Slickensided, highly weathered surfaces with soft clay coatings or fillings |
| STRUCTURE  |    | DECREASING SURFACE QUALITY →                             |  |
| 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 |  |  |
| 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<br>Very rough, fresh unweathered surfaces                  | VERY POOR<br>Very smooth, slickensided or highly weathered surfaces with soft clay coating or fillings |
|   |   | GOOD<br>Rough, slightly weathered or oxidised surfaces               | VERY POOR<br>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   |

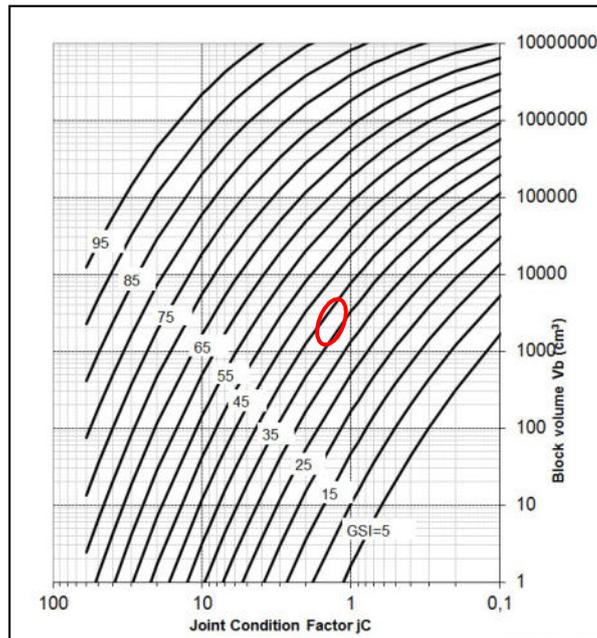
N/A Means geologically impossible combination. In the non - shadowed areas, such rockmasses are not impossible to find but it is very unusual

→ 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 |                        |                     |                         |



## RILIEVO GEOSTRUTTURALE

| Codice rilievo: | RS_04         | Coordinate UTM-WGS 84 (33T)  |           | Quota<br>[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

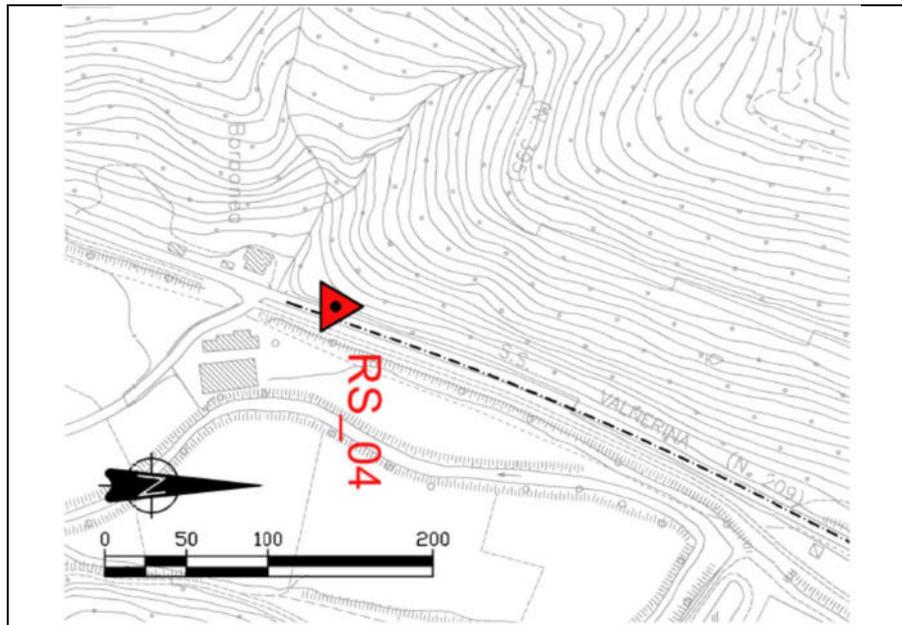


Fig.1. Carta di localizzazione del rilievo strutturale

### DOCUMENTAZIONE FOTOGRAFICA

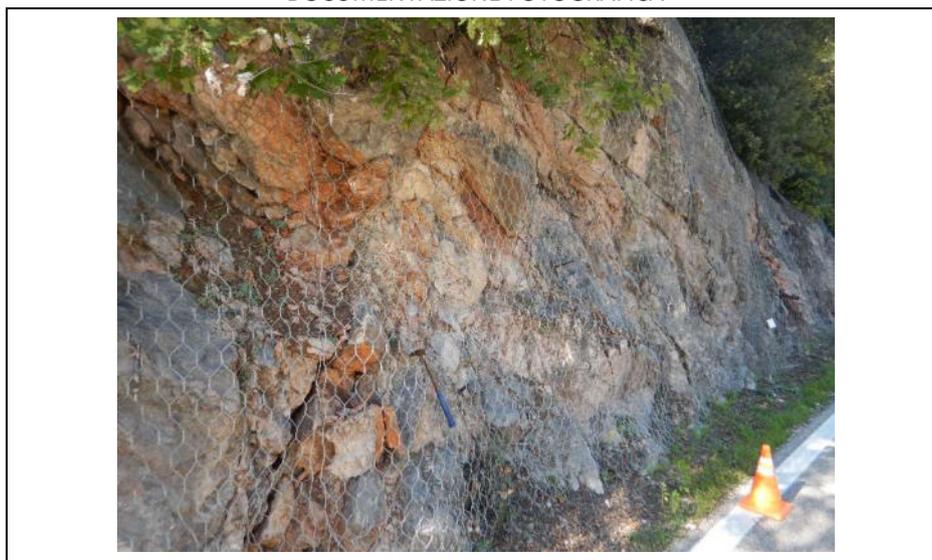


Fig.2. Vista d'insieme dell'affioramento

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 |

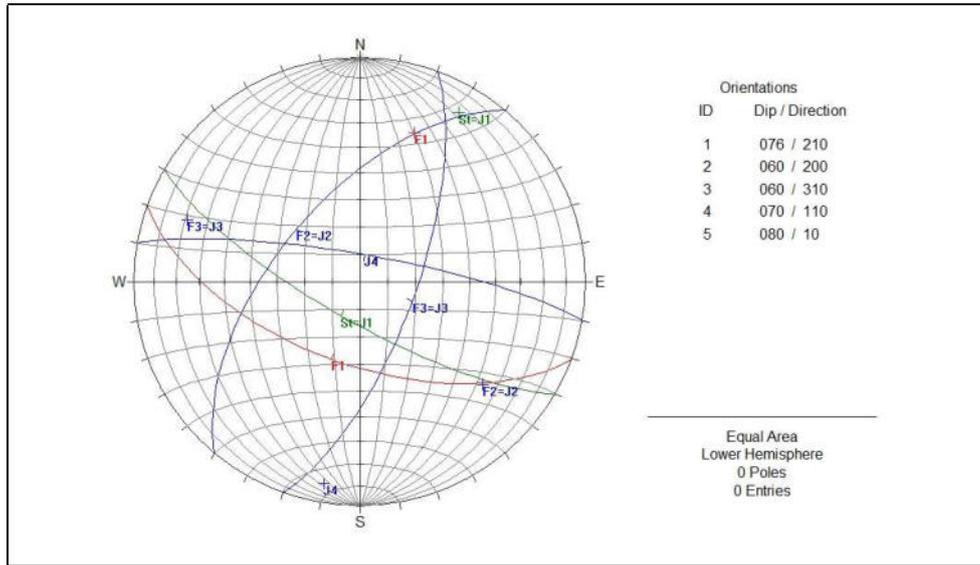
Note:

- 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 ( $\beta$ )  
*Palmstrøm (2005)*

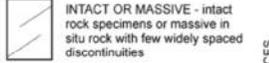
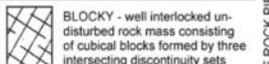
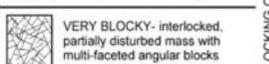
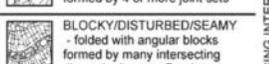
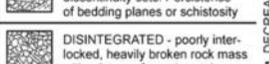
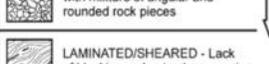
| Volume dei blocchi ( $V_b$ ) – misurati visivamente in sito [cm <sup>3</sup> ] |           |     |        | Fattore di forma del blocco    |                  |
|--|-----------|-----|--------|--------------------------------|------------------|
| Dimensione dei blocchi   | Frequente | Min | Max    | Palmstrøm, 2005                |                  |
|  |           |     |        | Extremely lung or flat blocks  | Beta ( $\beta$ ) |
| 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   | <b>32 - 50</b>   |
| <b><math>V_b = L1 \times L2 \times L3</math></b>                               | 52000     | 640 | 360000 | Cubical blocks                 | 27 - 32          |

VALUTAZIONE DEL GSI (GEOLOGICAL STRAIN INDEX)

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

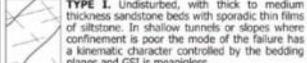
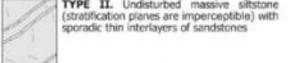
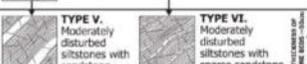
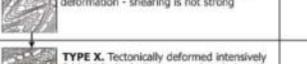
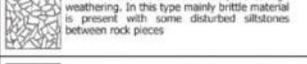
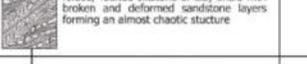
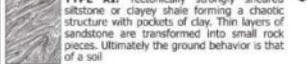
Marinos V. (2007) – Determinazione GSI per rocce flyschoidi

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> |     | VERY GOOD<br>Very rough, fresh unweathered surfaces      | VERY POOR<br>Slickensided, highly weathered surfaces with soft clay coatings or fillings |
|  |     | GOOD<br>Rough, slightly weathered, iron stained surfaces | VERY POOR<br>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  | N/A  | 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   |  |
|  | 10  |  |  |
|  | N/A | N/A  |  |
|  | N/A |  |  |
|  |     |  |  |

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> |     | VERY GOOD<br>Very rough, fresh unweathered surfaces                  | VERY POOR<br>Very smooth, slickensided or highly weathered surfaces with soft clay coating or fillings |
|   |     | GOOD<br>Rough, slightly weathered or oxidised surfaces               | VERY POOR<br>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 massive siltstone (stratification planes are imperceptible) with sporadic thin interlayers of sandstones</p>  | 80  | I  | II   |
|  <p>TYPE II. Undisturbed massive siltstone (stratification planes are imperceptible) with sporadic thin interlayers of sandstones</p>  | 70  | I  | II   |
|  <p>TYPE III. Moderately disturbed sandstones with thin films of interlayers of siltstone</p>   | 60  | III  | IV   |
|  <p>TYPE IV. Moderately disturbed rockmass with sandstone and siltstone similar amounts</p>  | 50  | III  | IV   |
|  <p>TYPE V. Moderately disturbed siltstones with sandstone interlayers</p>  | 40  | V  | VI   |
|  <p>TYPE VI. Moderately disturbed siltstones with sparse sandstone interlayers</p>   | 30  | V  | VI   |
|  <p>TYPE VII. Strongly disturbed, folded rockmass that retains its structure, with sandstone and siltstone in similar extend</p>   | 20  | VII  | VIII   |
|  <p>TYPE VIII. Strongly disturbed, folded rockmass, with siltstones and sandstone interlayers. The structure is retained and deformation - shearing is not strong</p>   | 10  | VII  | VIII   |
|  <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 | IX   | X  |
|  <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 | IX   | X  |
|  <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  | XI   |
|  <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  | XI   |

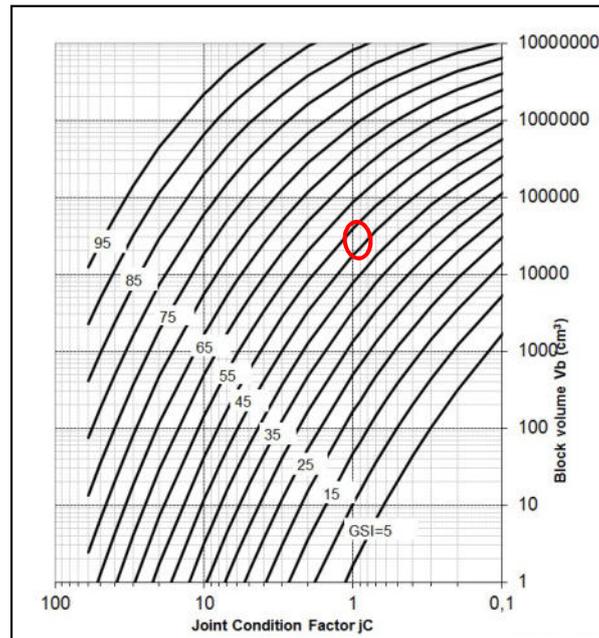
N/A Means geologically impossible combination. In the non - shadowed areas, such rockmasses are not impossible to find but it is very unusual

→ 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 |
| 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                |   |

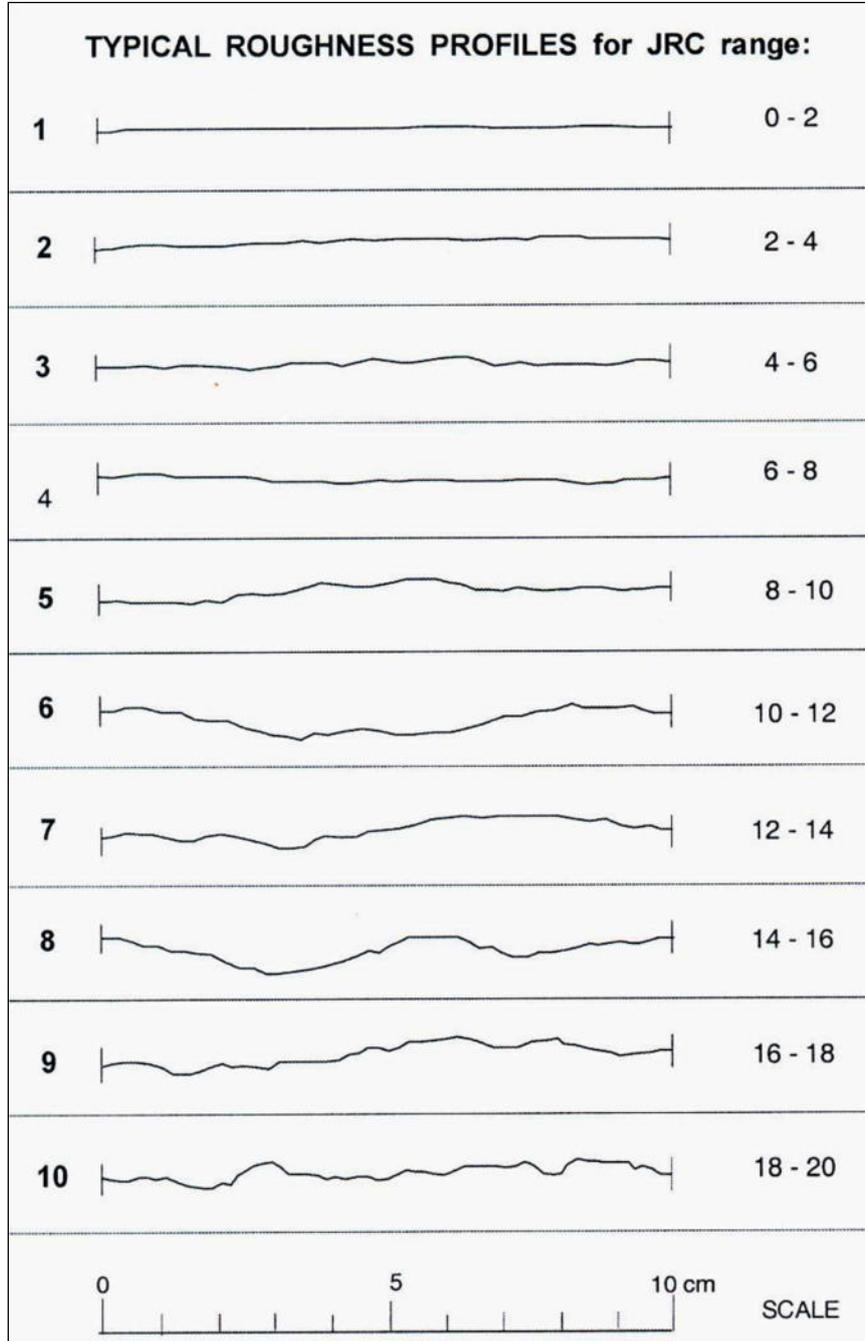
## 2\_Caratteristiche geomeccaniche delle discontinuità

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

| "RATINGS" EVALUATION – MÉTODO PALMSTRØM (2000 - 2005)                                   |   |  |   |                     |                        |                         |
|---|---|--|---|---------------------|------------------------|-------------------------|
| Joint Condition Factor $j_C$  |   | $j_C$ (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<br>[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

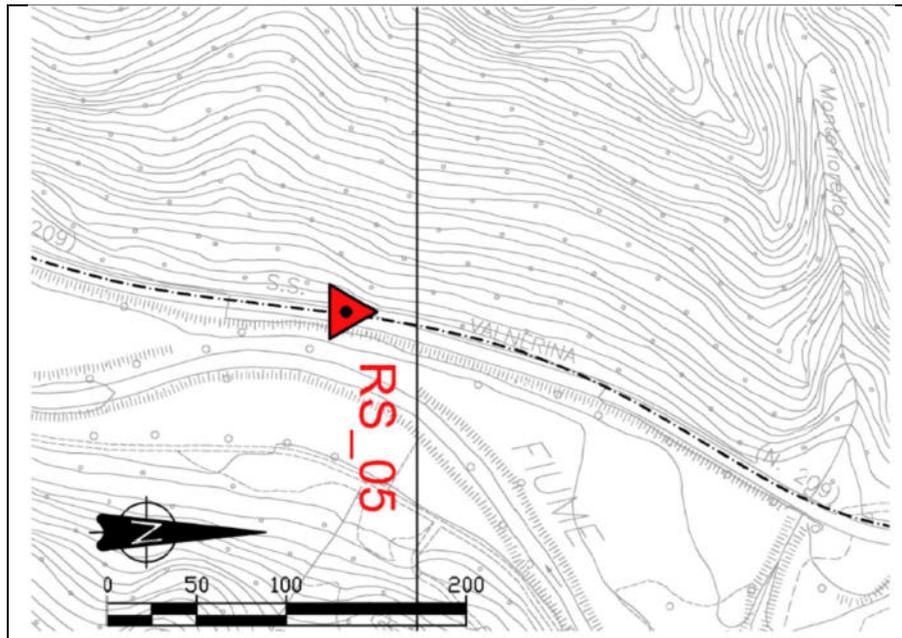


Fig.1. Carta di localizzazione del rilievo strutturale

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  |
| <b>J1</b>   | 180          | 68    | S3 (S4)                             | P3 (P4)     | R4       | C4 (C3)              | A5 (A4)  | F7          | secco                 | 8-10 |
| <b>F=J2</b> | 70           | 34    | S3                                  | P3 (P2)     | R4 (R6)  | C3                   | A1       | -           | secco                 | 6-8  |
| <b>J3</b>   | 100          | 88    | S3 (S2)                             | P3          | R4       | C3                   | A2       | -           | secco                 | 8-10 |
| <b>J4</b>   | 198          | 66    | S3                                  | P3          | R4       | C4                   | A5       | -           | secco                 | 8-10 |

Note:

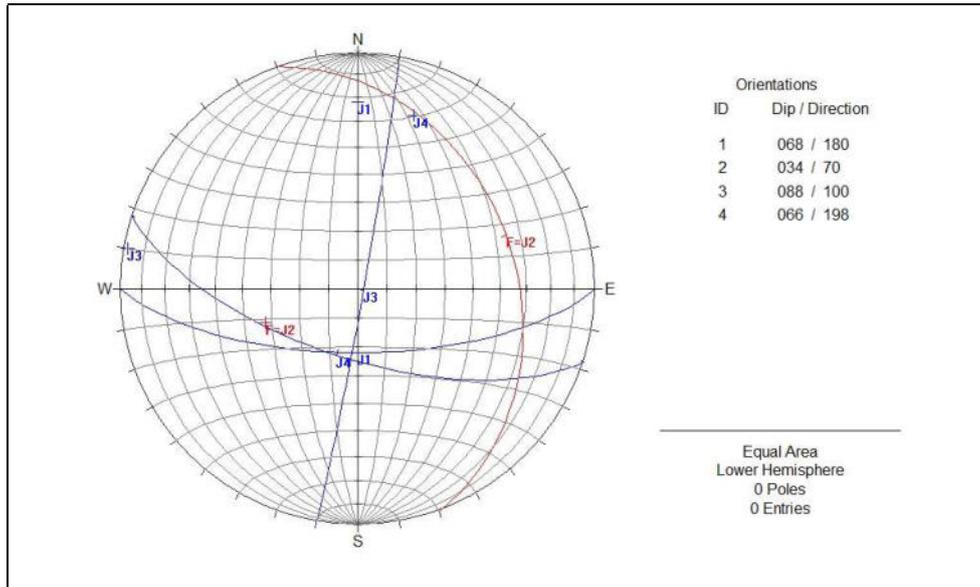
- St: Stratificazione; J: Giunto, frattura; F: Faglia, discontinuità tettonica.
- I termini tra parentesi descrivono caratteristiche subordinate.

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

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

Relazione sui rilievi geologico strutturali di dettaglio

PROIEZIONE STEREOGRAFICA DELLE DISCONTINUITA'



VOLUME DEI BLOCCHI ( $V_b$ ) E FATTORE DI FORMA DEL BLOCCO ( $\beta$ )  
*Palmstrøm (2005)*

| Volume dei blocchi ( $V_b$ ) – misurati visivamente in sito [cm <sup>3</sup> ] |           |     |        | Fattore di forma del blocco    |                  |
|--|-----------|-----|--------|--------------------------------|------------------|
| Dimensione dei blocchi   | Frequente | Min | Max    | Palmstrøm, 2005                | Beta ( $\beta$ ) |
|  |           |     |        | 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   | <b>32 - 50</b>   |
| <b><math>V_b = L1 \times L2 \times L3</math></b>                               | 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  |  |
|---|----|---|--|
| 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. |    | VERY GOOD<br>Very rough, fresh unweathered surfaces       | VERY POOR<br>Slackensided, highly weathered surfaces with soft clay coatings or fillings               |
| STRUCTURE   |    | GOOD<br>Rough, slightly weathered, iron stained surfaces  | POOR<br>Slackensided, highly weathered surfaces with compact coatings or fillings or angular fragments |
| DECREASING INTERLOCKING OF ROCK PIECES  |    | FAIR<br>Smooth, moderately weathered and altered surfaces | VERY POOR<br>Slackensided, 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  |
| BLOCKY - well interlocked undisturbed rock mass consisting of cubical blocks formed by three intersecting discontinuity sets  | 80 |   | N/A  |
| VERY BLOCKY - interlocked, partially disturbed mass with multi-faceted angular blocks formed by 4 or more joint sets  | 70 |   | N/A  |
| BLOCKY/DISTURBED/SEAMY - folded with angular blocks formed by many intersecting discontinuity sets. Persistence of bedding planes or schistosity  | 60 |   | N/A  |
| DISINTEGRATED - poorly interlocked, heavily broken rock mass with mixture of angular and rounded rock pieces  | 50 |   | N/A  |
| LAMINATED/SHEARED - Lack of blockiness due to close spacing of weak schistosity or shear planes   | 40 |   | N/A  |
|   | 30 |   | N/A  |
|   | 20 |   | N/A  |
|   | 10 |   | 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) |  |
|--|---|--|--|
| 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. |   | VERY GOOD<br>Very rough, fresh unweathered surfaces                  | VERY POOR<br>Very smooth, slickensided or highly weathered surfaces with soft clay coating or fillings           |
| STRUCTURE AND COMPOSITION  |   | GOOD<br>Rough, slightly weathered or oxidised surfaces               | POOR<br>Very smooth, occasionally slickensided surfaces with compact coatings or fillings with angular fragments |
| DECREASE OF THE QUALITY OF DISCONTINUITIES   |   | FAIR<br>Smooth, moderately weathered and altered surfaces            | VERY POOR<br>Very smooth, slickensided or highly weathered surfaces with soft clay coating or fillings           |
| 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   | 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   | N/A  |
| TYPE V. Moderately disturbed siltstones with sandstone interlayers   | TYPE VI. Moderately disturbed siltstones with sparse sandstone interlayers  | 60   | 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   | 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   | N/A  |
| 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   | N/A  |
|  |   | 20   | N/A  |
|  |   | 10   | N/A  |

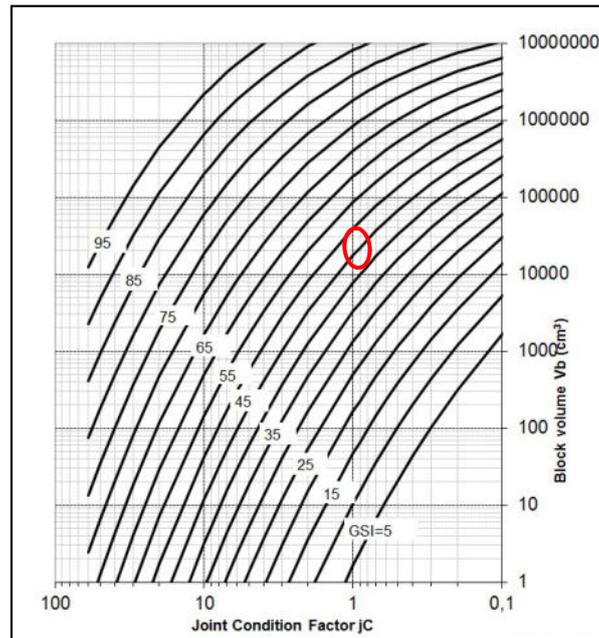
N/A Means geologically impossible combination. In the non - shadowed areas, such rockmasses are not impossible to find but it is very unusual

→ 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                |   |

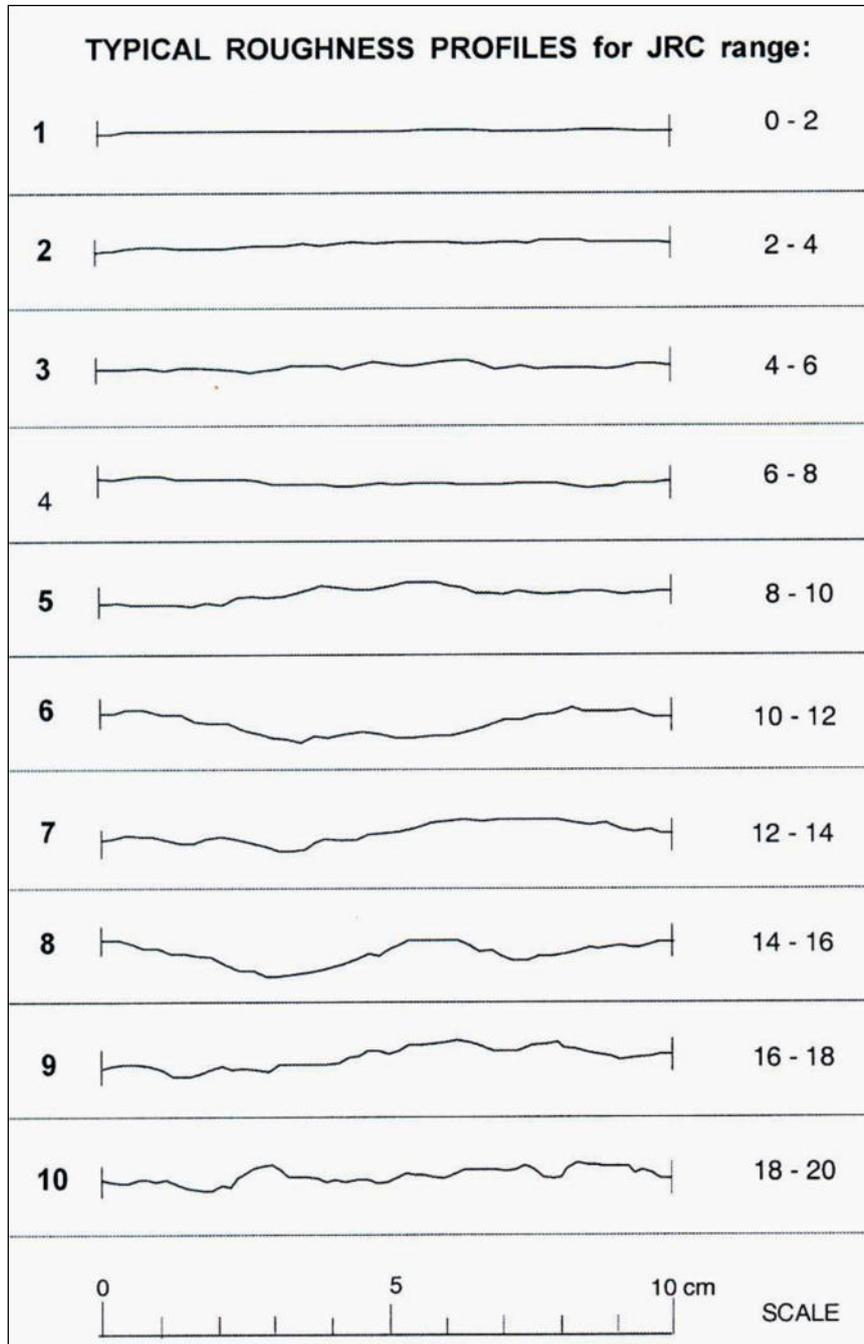
## 2\_Caratteristiche geomeccaniche delle discontinuità

"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*



Relazione sui rilievi geologico strutturali di dettaglio

**RILIEVO GEOSTRUTTURALE**

| Codice rilievo: | RS_06         | Coordinate UTM-WGS 84 (33T)       |           | Quota<br>[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

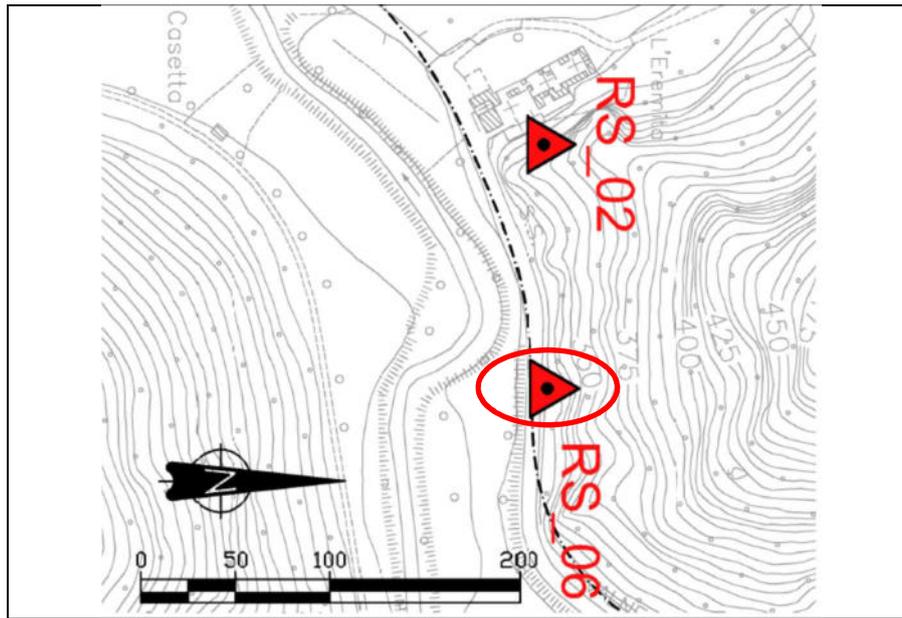


Fig.1. Carta di localizzazione del rilievo strutturale

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 |

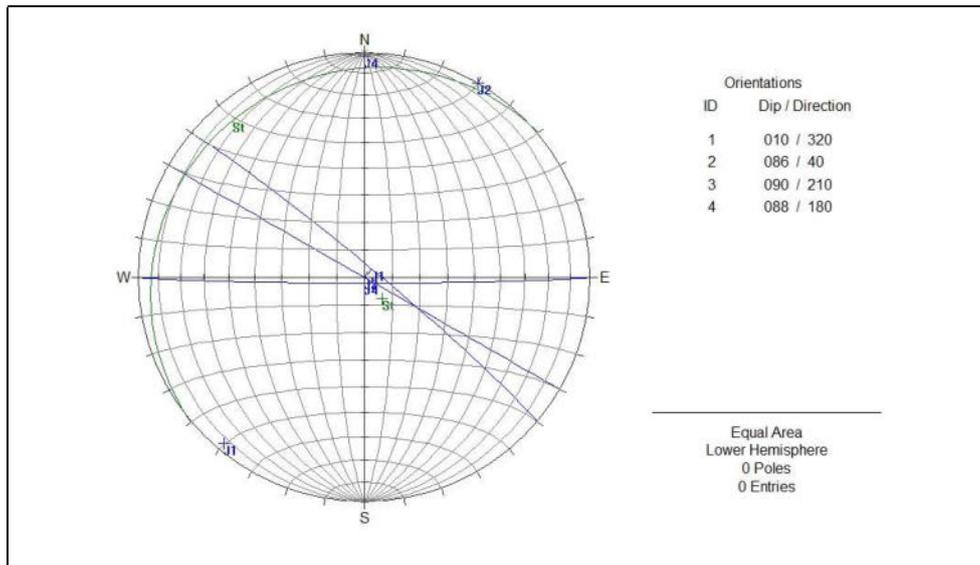
Note:

- 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 $jC$ (Palmstrøm) = $jR \times jL / jA$ |      |      |
|----------|--|------|------|
|          | $jR$   | $jL$ | $jA$ |
| 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 ( $\beta$ )  
*Palmstrøm (2005)*

| Volume dei blocchi ( $V_b$ ) – misurati visivamente in sito [cm <sup>3</sup> ] |           |     |        | Fattore di forma del blocco    |                  |
|--|-----------|-----|--------|--------------------------------|------------------|
| Dimensione dei blocchi   | Frequente | Min | Max    | Palmstrøm, 2005                |                  |
|  |           |     |        | Extremely lung or flat blocks  | Beta ( $\beta$ ) |
| 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   | <b>32 - 50</b>   |
| <b><math>V_b = L1 \times L2 \times L3</math></b>                               | 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<br>Very rough, fresh unweathered surfaces      | VERY POOR<br>Slickensided, highly weathered surfaces with soft clay coatings or fillings |
|  |    | GOOD<br>Rough, slightly weathered, iron stained surfaces | VERY POOR<br>Slickensided, highly weathered surfaces with soft clay coatings or fillings |
| STRUCTURE  |    | DECREASING SURFACE QUALITY →                             |  |
| 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 |  |  |
| 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<br>Very rough, fresh unweathered surfaces                  | VERY POOR<br>Very smooth, slickensided or highly weathered surfaces with soft clay coating or fillings |
|   |   | GOOD<br>Rough, slightly weathered or oxidised surfaces               | VERY POOR<br>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  |

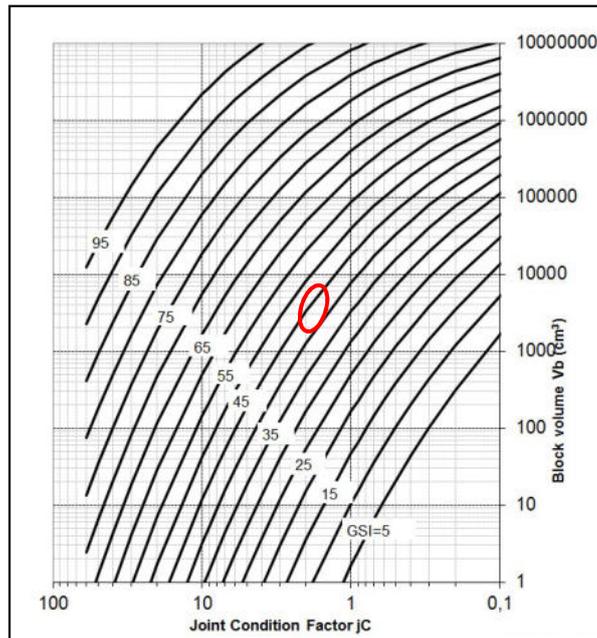
N/A Means geologically impossible combination. In the non - shadowed areas, such rockmasses are not impossible to find but it is very unusual

→ 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)

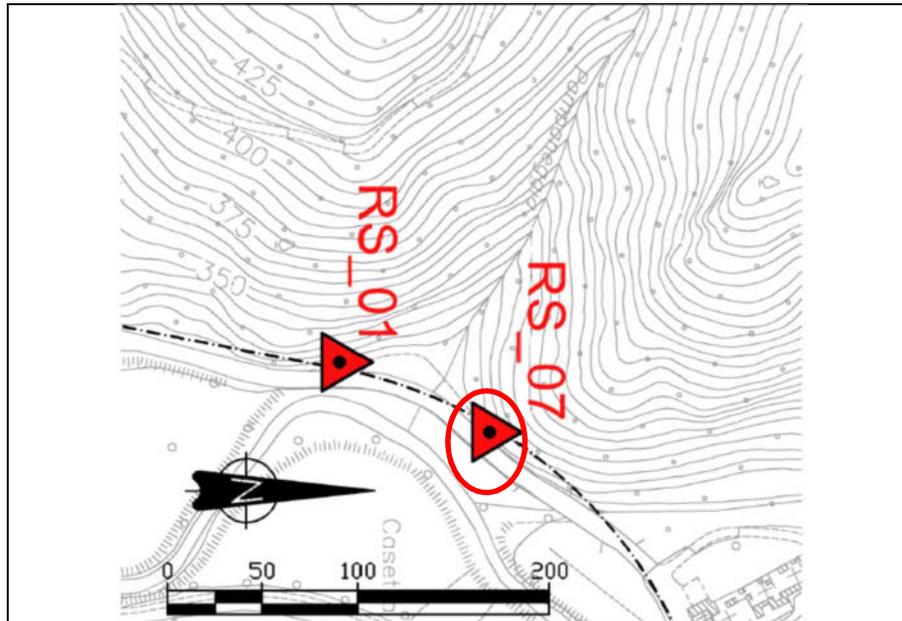
| "RATINGS" EVALUATION – MÉTODO PALMSTRØM (2000 - 2005)                                   |   |  |   |                        |                     |                         |
|---|---|--|---|------------------------|---------------------|-------------------------|
| Joint Condition Factor $j_C$  |   | $j_C \text{ (Palmstrøm)} = j_R \times j_L / j_A$           |   |                        |                     |                         |
| 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 |                        |                     |                         |



## RILIEVO GEOSTRUTTURALE

| Codice rilievo: | RS_07         | Coordinate UTM-WGS 84 (33T)       |           | Quota<br>[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  |
| <b>St=J1</b> | 260          | 82    | S2 (S3)                             | P3 (P4)     | R4       | C3                   | A4 (A5)  | -           | secco                 | 8-10 |
| <b>F</b>     | 248          | 62    | S5                                  | P3 (P4)     | R4 (R5)  | C4                   | A5       | F6          | secco                 | 6-8  |
| <b>J2</b>    | 330          | 82    | S2 (S3)                             | P2 (P3)     | R4       | C3                   | A2       | -           | secco                 | 8-10 |
| <b>J3</b>    | 180          | 60    | S2 (s2)                             | P2 (P3)     | R4       | C3                   | A2       | -           | secco                 | 8-10 |

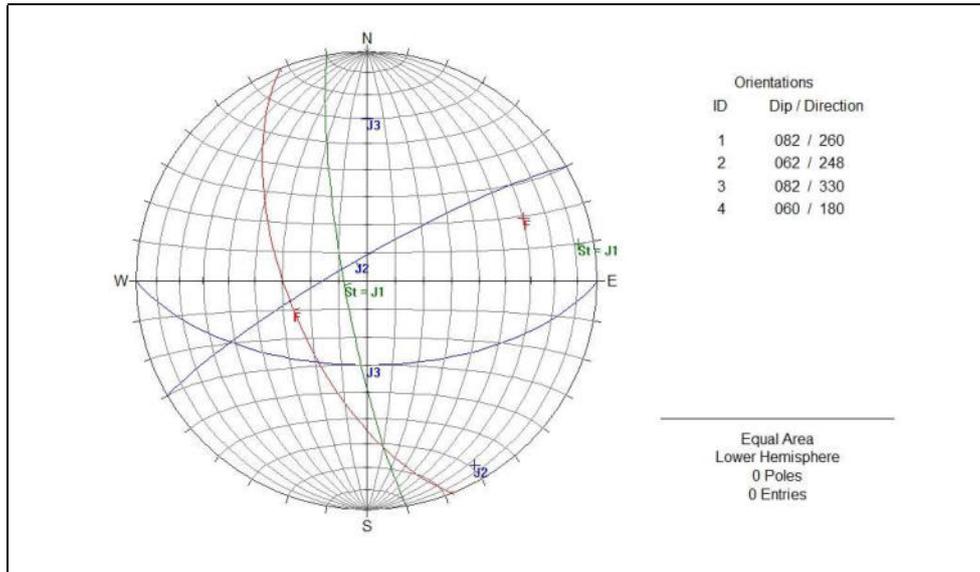
Note:

- 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 |
| <b>St = J1</b> | 2  | 0,75 | 3  |
| <b>F</b>       | 1  | 0,75 | 4  |
| <b>J2</b>      | 2  | 2    | 2  |
| <b>J3</b>      | 2  | 2    | 2  |

PROIEZIONE STEREOGRAFICA DELLE DISCONTINUITA'



VOLUME DEI BLOCCHI ( $V_b$ ) E FATTORE DI FORMA DEL BLOCCO ( $\beta$ )  
*Palmstrøm (2005)*

| Volume dei blocchi ( $V_b$ ) – misurati visivamente in sito [cm <sup>3</sup> ] |           |     |       | Fattore di forma del blocco    |                  |
|--|-----------|-----|-------|--------------------------------|------------------|
| Dimensione dei blocchi   | Frequente | Min | Max   | Palmstrøm, 2005                | Beta ( $\beta$ ) |
|  |           |     |       | 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   | <b>32 - 50</b>   |
| <b><math>V_b = L1 \times L2 \times L3</math></b>                               | 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.

| STRUCTURE  | SURFACE CONDITIONS                                  |  |   |  |
|--|---|--|---|--|
|  | VERY GOOD<br>Very rough, fresh unweathered surfaces | GOOD<br>Rough, slightly weathered, iron stained surfaces | FAIR<br>Smooth, moderately weathered and altered surfaces | POOR<br>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   |   |  |
| 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   |

DECREASING INTERLOCKING OF ROCK PIECES

DECREASING SURFACE QUALITY

VERY POOR  
Slickensided, 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   | SURFACE CONDITIONS OF DISCONTINUITIES (Predominantly bedding planes) |  |   |  |
|---|--|--|---|--|
|   | VERY GOOD<br>Very rough, fresh unweathered surfaces                  | GOOD<br>Rough, slightly weathered or oxidised surfaces | FAIR<br>Smooth, moderately weathered and altered surfaces | POOR<br>Very smooth, occasionally slickensided surfaces with compact coatings or fillings with angular fragments |
| <b>TYPE I.</b> 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  |
| <b>TYPE II.</b> Undisturbed massive siltstone (stratification planes are imperceptible) with sporadic thin interlayers of sandstones  |  |  |   | N/A  |
| <b>TYPE III.</b> Moderately disturbed sandstones with thin films of interlayers of siltstone  | 60   | III  | IV  | V  |
| <b>TYPE IV.</b> Moderately disturbed rockmass with sandstone and siltstone similar amounts  |  |  |   | N/A  |
| <b>TYPE V.</b> Moderately disturbed siltstones with sandstone interlayers   |  |  |   | N/A  |
| <b>TYPE VI.</b> Moderately disturbed siltstones with sparse sandstone interlayers   |  |  |   | N/A  |
| <b>TYPE VII.</b> Strongly disturbed, folded rockmass that retains its structure, with sandstone and siltstone in similar extend   | N/A  |  | VII   | VIII   |
| <b>TYPE VIII.</b> Strongly disturbed, folded rockmass, with siltstones and sandstone interlayers. The structure is retained and deformation - shearing is not strong  |  |  |   |  |
| <b>TYPE IX.</b> 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  |
| <b>TYPE X.</b> Tectonically deformed intensively folded/ faulted siltstone or clay shale with broken and deformed sandstone layers forming an almost chaotic structure  |  |  |   |  |
| <b>TYPE XI.</b> 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

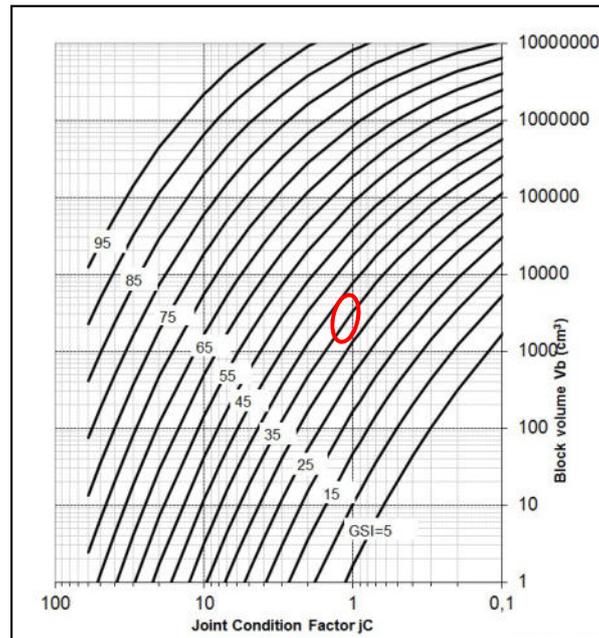
N/A Means geologically impossible combination. In the non - shadowed areas, such rockmasses are not impossible to find but it is very unusual

→ 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\_Profili tipici di scabrezza (rugosità)**

*Barton & Choubey, 1977*

