INTRODUCTION TO RDA

As indicated previously, RDA is divided into three stages:

Stage One: Ratings are applied to four key parameters to obtain a rating for the rock mass. This rating is adjusted to take account of external factors and excavated slope characteristics. The resulting adjusted RDA_A Class is used to obtain an indication of the general approach that should be taken to slope stabilization and treatment work .

Other documents to refer to: 2. Introduction to RDA, 3. RDA Stage One.

Stage Two: The nature of the deterioration hazard, notably the transport mechanism involved, is assessed qualitatively with reference to the type of rock mass and evidence from slope morphology.

Other documents to refer to: 5. Deterioration Transport Mechanisms, 6. Deterioration Morphology.

Stage Three: The findings of stages one and two are used to obtain guidance on appropriate slope protection and treatment works.

Other documents to refer to: 7. Mitigation Matrix.

RDA STAGE TWO: ROCK MASS TYPES

In RDA stage two the nature of the potential deterioration hazard is evaluated. The first step is to establish what type of rock mass the slope under consideration is cut into. Three primary types of rock mass, each sub-divided, have been identified from field investigation, defined largely on the basis of the spatial distribution of open fractures and rock mass structure. The rock mass types are massive (weak or strong), layered (normal, fissile or composite) and blocky (regular or irregular). In addition, several subsidiary types of rock mass are identified, namely intensely fractured zones, soluble rock masses and composite structure. These represent structural and/or lithological characteristics which may be superimposed on the primary rock mass type. Certain types of rock mass have a strong lithological association and, therefore, material properties are also reflected in the classification. A summary table of rock mass types is provided in Figure 1. More detailed descriptions of each rock mass type are provided in Figures 2 to 9. The latter indicate the geological occurrence of each type of rock mass, associated deterioration transport mechanisms, special characteristics and a typical RDA_A Class. For existing slopes, it is relatively simple to determine, on the basis of visual, inspection the rock mass type which most closely matches that under consideration. When assessing slopes prior to excavation it will be necessary to make an informed estimate based on desk and field survey data.

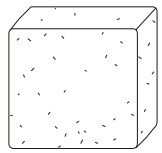
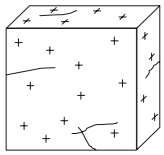
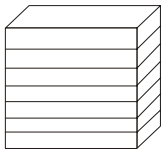
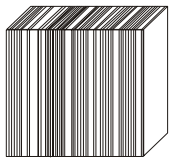
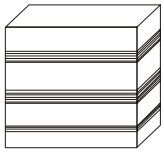
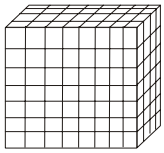
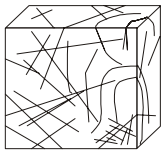
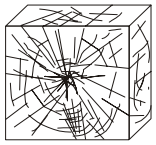
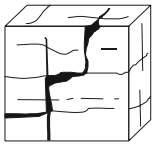
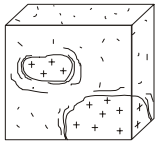
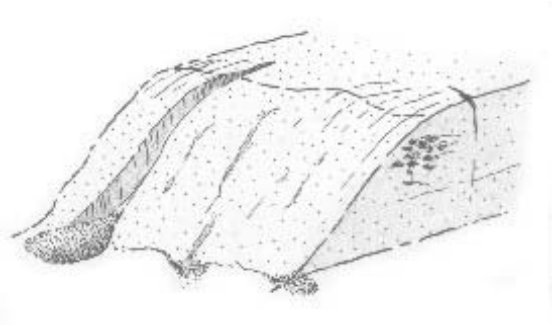
	Deterioration transport mechanisms	Typical RDA_A Class	Description and deterioration characteristics
PRIMARY ROCK MASS TYPES			
	**WEAK MASSIVE** Grain ravelling, grainfall, wash erosion, contour scaling, (minor: *stonefall*).	Sed: **2/3+**. Ign: **Rare** Met: **Rare**	Weak rock masses with no dominant structure or very thickly bedded. Slopes prone to erosion by surface runoff and to penetrative material weathering.
	**STRONG MASSIVE** Wash erosion, contour scaling, stonefall, blockfall, (minor: *stone ravelling, flaking, slabfall, rockfall*)	Sed: **2** Ign: **1/2** Met: **1+**	Strong rock masses with no dominant structure or a very wide fracture spacing of c.1 to 3m (Deere 1963). Slopes prone to solution, wash erosion, scaling and fragmentation from root wedging. Rebound fracturing in deep excavations.
	**LAYERED** Stonefall, stone ravelling, wash erosion, blockfall (minor: *grain ravelling, flaking, solution, contour scaling, rockfall*)	Sed: **2/3** Ign: **2/3** Met: **1-4**	Repeated lithological or structural layering (any angle). Can be very stable, but prone to erosion, flaking and collapse along chutes where folded or vertically layered.
	**FISSILE LAYERED** Flaking, grain ravelling, wash erosion (minor: *stone ravelling, stonefall, rockfall*).	Sed: **4/5** Ign: **Rare** Met: **1-4**	Very thinly layered rock due to thin bedding, schistosity, cleavage or lamination. Rapid breakdown, debris production and slope regression common.
	**COMPOSITE LAYERED** Stonefall, stone ravelling (minor: *block ravelling, flaking, wash erosion, contour scaling, rockfall*).	Sed: **3+** Ign: **Rare** Met: **1/2**	Inter-layered strata having contrasting material properties. Differential weathering leads to undermining, producing stonefall and occasional overhang collapse. Groundwater flow may concentrate in weaker layers.
	**REGULAR BLOCKY** Stone ravelling, stonefall, blockfall, rockfall (minor: *grain ravelling, flaking, wash erosion, contour scaling*).	Sed: **3+** Ign: **2** Met: **2/3**	Orthogonal blocky structure (or rubbly in chalk and oolitic limestone) due to intense and regular intersection of three or more sets of fractures. Deterioration relates to rock mass properties. Blocky rock masses experience high frequency falls.
	**IRREGULAR BLOCKY** Stone ravelling, stonefall, rockfall (minor: *grain ravelling, flaking, wash erosion, blockfall*).	Sed: **2-4** Ign: **2/3** Met: **1-3**	Irregularly shaped and variably sized blocks due to non-patterned intersection of fractures. Deterioration involves large blocks or large volumes of material. Rarely, small-scale debris flows in weathered regolith.
SUBSIDIARY ROCK MASS TYPES			
INTENSELY FRACTURED ZONES  Intense, localised fracturing and shattering, producing loose structure. Vulnerable to root growth. Intense ravelling, rockfall and rare debris flows.			
SOLUBLE ROCK MASSES  Dissolution of rock leading to fracture enlargement, micro-solution and karstification. Collapse of solution cavities leads to rockfall and blockfall.			
COMPOSITE STRUCTURE  Contrasting rock mass structures in close proximity, in a non-uniform distribution. Vulnerable to differential weathering and overhang collapse.			

Figure 1: Summary of rock mass types

WEAK MASSIVE

Description: Weak (eg <20MPa) rock masses with no dominant structure (ie essentially homogeneous), or with very wide fracture spacing. Might have occasional fractures or many closed discontinuities.



Occurrence: Occurs only in sedimentary rocks, usually those which are granular, friable, perhaps with poor cementing. Examples include weakly bonded sandstones (eg bonded with calcite, clay, gypsum); highly weathered gritstone and sandstone; mudstone; marl; weak chalk and weak oolitic limestone.

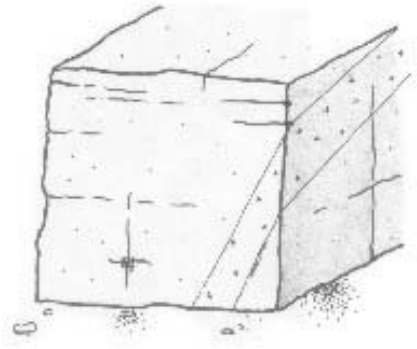
Special characteristics: Most deterioration relates to material breakdown and erosion. Slopes are prone to erosion by surface runoff and to penetrative material weathering, especially in damp environments. Might be vulnerable to wind erosion. Honeycomb weathering common in sandstones. Might behave like a soil if very weak. Reduction in groundwater and surface water flow critical for erosion control and minimisation of material weathering. Vegetation cover useful for ground reinforcement

Associated deterioration transport mechanisms: Grain ravelling, grainfall, wash erosion, contour scaling, (minor: *stonefall*). **Typical RDA_A Class**: (Sed) **2/3+**. Rare in igneous and metamorphic rock.

Figure 2: Classification of rock mass types: ***Weak massive***

STRONG MASSIVE

Description: Strong rock masses with no dominant structure (ie essentially homogeneous), or a very wide fracture spacing of around 1 to 3m (Deere 1963). Might have occasional fractures or many closed discontinuities such as fabric, laminations and bedding.



Occurrence: Occurs in a wide range of rock types, largely those unaffected by stress release, weathering and excavation induced fracturing. Examples include very thickly bedded gritstone and crystalline limestone, tough breccia and slightly metamorphosed sediments. Also structureless granite, basalt and tuff, and intact gneiss.

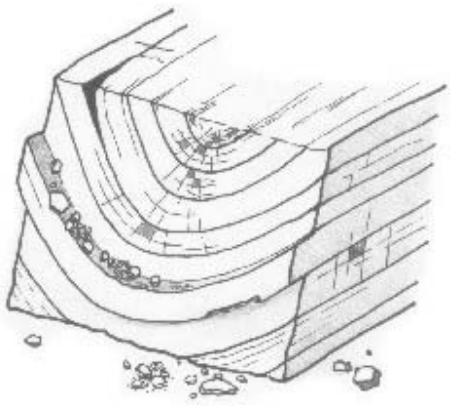
Special characteristics: Commonly resistant to deterioration except for localised wash erosion, scaling and fragmentation from local root wedging or solution. Might be susceptible to rebound fracturing, especially in deep excavations. Long term material weathering can occur.

Associated deterioration modes: Wash erosion, contour scaling, stonefall, blockfall, (minor: *stone ravelling, flaking, slabfall, rockfall*). **Typical RDA_A Class:** (Sed) 2- (Ign) 1/2 (Met) 1+.

Figure 3: Classification of rock mass types: ***Strong massive***

LAYERED

Description: Repeated layering of strata at any dip angle. Strata can be lithological (eg bedding) or structural (eg jointing). Prismatic (or columnar) structure is a sub-group (also for *regular blocky*), formed from the intersection of two persistent fracture sets. The two-dimensional trace of prismatic structure might appear as vertical layering.



Occurrence: Occurs in a wide range of bedded sedimentary rocks such as limestone, shale, sandstone and gritstone. Also in igneous rocks with repeated layering such as lavas (basalt, dolerite) and volcaniclastics. Occurs in foliated and banded metamorphic rocks such as slate, schist and some gneisses and metasediments. Can also occur in igneous rocks where a single set of closely spaced, regular joints is present.

Special characteristics: Horizontally layered masses can be very stable, but where folded or vertically layered, can be prone to erosion, flaking and collapse along chutes. Dip angle and direction control sliding of large blocks. Fall of isolated stones and blocks is the most common form of deterioration.

Associated deterioration modes: Stonefall, stone ravelling, wash erosion, blockfall (minor: *solution, grain ravelling, flaking, contour scaling, rockfall*). **Typical RDA_A Class:** (Sed) 2/3 (Ign) 2/3 (Met) 1 to 3.

Figure 4: Classification of rock mass types: ***Layered***

FISSILE LAYERED

Description: Very thinly layered rock due to thin bedding, schistocity, cleavage or lamination. The term schistose structure can be applied where appropriate. Fissile structure tends to be dominated by regular, tight aperture discontinuity planes. Schistose structure is characterised by small scale, irregular, deformed foliation planes.

Occurrence: Occurs in clay or mica-rich rock including shale, very thinly bedded flaggy sandstone, cleaved metasediment, slate, schist and phyllite. Commonly occurs as a distinct zone in composite rock masses. Rare in igneous rock.

Special characteristics: Prone to material weathering and surface erosion, particularly where cyclic wetting and drying occurs.

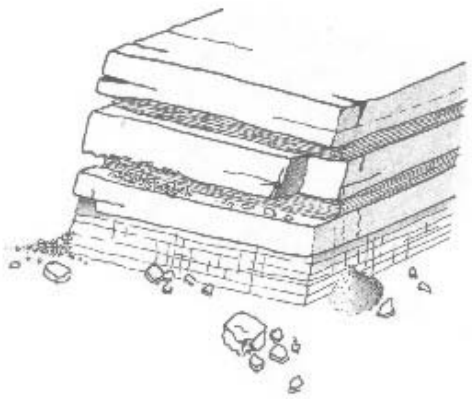
Usually produces large amounts of debris rapidly, producing significant slope regression in engineering time. More competent material can be classified as layered.

Associated deterioration modes: Flaking, grain ravelling, wash erosion (minor: *stone ravelling, stonefall, rockfall*). **Typical RDA_A Class**: (Sed) **4/5** (Met) **1 to 4**. Rare in igneous rock.

Figure 5: Classification of rock mass types: ***Fissile layered***

COMPOSITE LAYERED

Description: Inter-layered strata having contrasting material properties.



Occurrence: Occurs in sedimentary and metamorphic rock masses with inter-layered sequences of strata with contrasting properties. Examples include Coal Measures sequences of interbedded sandstone, shale and limestone; metamorphosed turbidite sequences; inter-bedded thin and thick layers of limestone. Can also occur locally at the site of unconformities. Can occur in interbedded lava sequences.

Special characteristics: Differential weathering of strata with contrasting properties. This leads to undermining, producing isolated and semi-continuous fall of stone sized material, and occasional collapse of overhangs. Protection or reinforcement of weaker strata essential to reduce undercutting and collapse of competent strata. Groundwater flow can be concentrated in the weaker, more porous layers.

Associated deterioration modes: Stonefall, stone ravelling (minor: *block ravelling, flaking, wash erosion, contour scaling, rockfall*). **Typical RDA_A Class**: (Sed) **3+** (Met) **1/2**. Rare in igneous rock.

Figure 6: Classification of rock mass types: ***Composite layered***

REGULAR BLOCKY

Description: Orthogonal blocky structure due to intense and regular intersection of three or more fracture sets. Prismatic (or columnar) structure is a rare sub-group (also for *layered*), formed from the intersection of two persistent fracture sets. The 2-D trace of prisms can appear as a regular blocky structure. *Rubbly* can be used as a suffix term for blocky structure in weak chalk and oolitic limestone.

Occurrence: Occurs in a wide range of moderately strong to strong sedimentary rocks (eg gritstone, strong sandstone, crystalline limestone and hard chalk). Also in igneous rocks with well developed jointing (eg granite, basalt, pegmatite and microgranite). Also in strong metamorphic rocks (eg gneiss and metasediment) and folded and faulted strata.

Special characteristics: Most deterioration relates to rock mass properties and material weathering is usually incidental. Fracturing often enhanced by stress release jointing. Blocky rock masses are commonly associated with high frequency falls.

Associated deterioration modes: Stone ravelling, stonefall, blockfall, rockfall (minor: *grain ravelling, flaking, wash erosion, contour scaling*). **Typical RDA_A Class**: (Sed) **3+** (Ign) **2** (Met) **2/3**.

Figure 7: Classification of rock mass types: ***Regular blocky***

IRREGULAR BLOCKY

Description: Irregularly shaped and variably sized blocks due to irregular fracture intersection. Rubbly can be used as a suffix for irregular blocky structure in weak chalk and oolitic limestone.

Occurrence: Occurs in rocks shattered by stress release, blasting and weathering. Found in moderately strong to strong sedimentary rocks (eg gritstone, strong sandstone, crystalline limestone and hard chalk). Also occurs in strong metamorphic rocks including gneiss and metasediments. Only occurs in igneous rocks where regular jointing is absent. These include pillow lavas, ignimbrite, tuff and some microgranites. Also occurs in weak chalk, particularly in association with nodular beds.

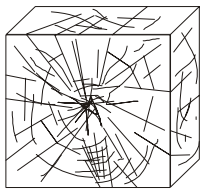
Special characteristics: Irregular fracturing associated with intensely folded and faulted rock, curved cooling or sheeting joints, shear zones, stress release, blasting and weathering. In strong rock masses, irregular shape of blocks causes tight interlocking, reducing block release potential. Deterioration tends to involve large blocks or volumes of material. Although rare, debris flow can occur in these rock masses.

Associated deterioration modes: Stone ravelling, stonefall, rockfall (minor: *grain ravelling, flaking, wash erosion, blockfall, debris flow*). **Typical RDA_A Class**: (Sed) **2 to 4** (Ign) **2/3** (Met) **1 to 3**.

Figure 8: Classification of rock mass types: ***Irregular blocky***

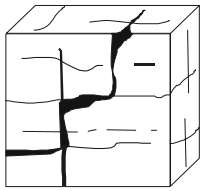
SUBSIDIARY ROCK MASSES

INTENSELY FRACTURED ZONES



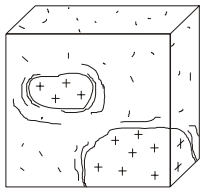
Description: Intense, localised fracturing and shattering, producing a very loose structure. **Occurrence:** All rock types. Usually associated with blast damage zones, plant roots, the hinges of tightly folded strata, faults and shear zones. **Special characteristics:** Vulnerable to root penetration, increased groundwater flow and direct disturbance. Commonly leads to local but intense ravelling, rockfall and debris flow.

SOLUBLE ROCK MASSES



Description: Solution of rock material, leading to fracture enlargement, micro-solution features and macro karstification in severe cases. **Occurrence:** Soluble rocks (eg crystalline and oolitic limestone, chalk), and rocks with soluble cement. **Special characteristics:** Collapse of solution cavities leads to rockfall and blockfall.

COMPOSITE STRUCTURE



Description: Two or more types of contrasting rock mass structure are present in close proximity, in a non-layered, non-uniform distribution. **Occurrence:** Examples include core-stones, igneous intrusions, buried channels and exposure of palaeo-weathering profiles. **Special characteristics:** Can lead to overhang collapse if differential weathering occurs.

Figure 9: Classification of rock mass types: ***Subsidiary rock masses***

References

DEERE, D. U. 1963. Technical description of rock cores for engineering purposes. *Felsmechanik und Ingenieurgeologie* **1** (1), 16-22.