## Weathering damage on Pharaonic sandstone monuments in Upper Egypt

## Classification of weathering forms

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LEVEL 1	GROUPS OF WEATHERING FORMS							
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LEVEL 2	MAIN WEATHERING FORMS							
LEVEL 3	INDIVIDUAL WEATHERING FORMS							
LEVEL 4	INDIVIDUAL WEATHERING FORMS WITH DIFFERENTIATION OF INTENSITIES							

Classification of weathering forms

Weathering forms are the visible results of weathering processes, which are initiated and controlled by weathering factors. Weathering forms represent an important parameter for the characterization, quantification and rating of stone weathering. A survey of weathering forms on the Pharaonic sandstone monuments in Upper Egypt was made. A wide range of weathering forms was observed characterizing loss of stone material, discoloration / deposits, detachment of stone material and fissures / deformation. A classification scheme of weathering forms - accompanied by a photoatlas was developed as basis for their objective and reproducible registration. Damage categories and damage indices were established for the rating of weathering damage. All weathering forms considering their type and intensity - were related to damage categories.

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	GROUP 1 OF WEATHERING FORMS			Contraction of the second	G	ROUP 3 OF WEATHERING FOR	MS			
MAIN		INTENSITIES OF	INTENSITIES OF DAMAGE	1 Part To	MAIN		INTENSITIES OF	INTENSITIES OF DAMAGE	0	
WEATHERING FORMS	WEATHERING FORMS	INDIVIDUAL WEATHERING FORMS	THE WEATHERING FORMS	adillace -	WEATHERING FORMS	WEATHERING FORMS	WEATHERING FORMS	FORMS CATEGORIES		
	Back weathering due to loss of scales Uniform loss of stone material parallel to the clean surface due to economic scaling	Depth of back weathering to	Intensity 1 1	THE PERSON NEW	GRANULAR	Granular disintegration into powder Detachment of smallest stone particles (stone nowler)	14 Mass of detaching Gp2		A STATE	
BACK	Back weathering due to loss of crusts	Intensity 1: < 0.5 CW1	Intensity 2 1	Provide Land Longer and	DISINTEGRATION Detechment of Individual	Granular disintegration into sand	Intensity 1: Jow Gp3		NOTON A TIME	
Uniform loss of stone material parallel to the	V Uniform loss of stone material parallel to the original stone due to detachmen of crusts with adherent stone material.	Intensity 3: 1 - 3 to	Intensity 4 3	1 2000	grains or small grain aggregates.	Detachment of small grains as individual grains or small grain aggregates (stone sand).	15 Intensity 3: Aigh G82 G83	Intensity 1 1		
original stone surface.	Back weathering due to loss of undefinable stone aggregates / pieces	Intensity 5: 5 - 10 ZW1	Intensity 5 4	2	CRUMBLY DISINTEGRATION	Crumbling Detectment of larger compact stone pieces Pu	16 Mass of detaching Pu1 stone material Pu2	Intensity 2 2	15	
	Uniform loss of stone material parallel to the original stone surface. The type of the preceding detachment stone material can	Intensity 6: 70 - 25 Intensity 7: > 25	Intensity 6 5	an to the second	Detachment of larger P	in the form of crumbs.	Intensity 1: Intensity 2: medium Pus	Intensity 3 3		
	Rounding / notching	ZWn Ro1		2- 0 -98 . A - 4-	compact stone pieces of irregular shape.	Detachment of larger compact stone pieces in the form of splinters.	Intensity 3: Aligh Priz			
	Relief by rounding of edges or notching / hollowing out. Conceve or convex soft forms.	) to Ro <sub>n</sub>		3	FLAKING	Single flakes	17 Mass of detaching eF1		- Maria	
	Alveolar weathering Relief in the form of alveolae. Ra	) Ra, to		Tenter of the	Detachment of small, thin stone pieces (flakes)	Detachment of one layer of flakes parallel to the stone surface.	Intensity 1: Inten		and the second	
	Form comparabel to honeycombs.	Depth of relief (cm) tR1		6919 200	parallel to the stone	Multiple flakes mF Detachment of a stack of flakes mF parallel to the stone surface.	Intensity 2: Medium III 1 Intensity 3: Algh IIIF2		16	
KELIEF Morphological change	Relief dependent on structural features such as bedding, foliation, banding etc. Fromently striped contern	Intensity 1: < 0.5 to	Intensity 2 1		surrace.	Scale due to tooling of the stone surface	Thickness of the scale qS <sub>1</sub>	Intensity 1 1		
of the stone surface due to partial or	Weathering out of stone components	Intensity 3: 1 - 3 Intensity 4: 3 - 5	Intensity 3 2		CONTOUR SCALING	Detachment of mainly thin scales due to tooling of the stone surface. qS	Intensity 1: >0.5 Intensity 2: 0.5 - 1 qS <sub>2</sub>	Intensity 2 1		
selective weathering.	Relief due to selective weathering of sensitive stone components (clay lenticles, nodes of limonite etc.) or due to break out of compact	Intensity 5: 5 - 10 to	Intensity 4 3	4		Single scale	Thickness of the scales	Intensity 1 1		
	Hole-shaped forms.	Intensity 7: > 25	Intensity 5 4		Detachment of larger, platy stone pieces parallel	Detachment of one layer of scales.	18 or the stack of scales to (cm) to	Intensity 2 1	The second second	
	Relief in the form of protruding compact stone components (pebbles, concretions) due to	) to	Intensity 6 5		to the stone surface, but not following any stone	Multiple scales	Intensity 2: 0.5-1 mS1	Intensity 3 2		
	Relief due to anthropogenic impact	Rh <sub>n</sub> aR <sub>1</sub>	Intensity 7 5		structure.	Detachment of a stack of scales. mS	19 Intensity 4: 3-5 to	Intensity 4 3		
	Relief in the form of scratches etc. aR	) to aR <sub>n</sub>		5	DETACHMENT OF		intensity 5: 25 mSn		(18)	
	Break out due to anthropogenic impact Break out due to war, vandalism etc. aO	Volume of break out to		2 1 8 3 4 300	STONE LAYERS	Splitting up	Number of detaching stone layers resp. splits Xv1	Intensity 1 2	Mr. Sugar	
BREAK OUT	Break out due to constructional cause	(cm <sup>2</sup> ) aO <sub>n</sub> Intensity 1: < 10 bO <sub>1</sub>	Intensity 1 1		STONE STRUCTURE X	Detachment of larger stone layers (sheets, plates) following any stone structure (bedding, etc.), but not the stone surface. Structural feature is not orientated parallel	Intensity 1: Jow Xv <sub>2</sub> Intensity 2: medium	Intensity 2 3		
Loss of compact	Break out due to statics etc. bO	Intensity 2: 10 - 125 to Intensity 3: 125 - 500 bOn	Intensity 3 3	Land - from al	Detachment of larger stone sheetes or plates following	parallel to the stone surface.	Intensity 3: high XV3	Intensity 3 4		
stone fragments.	Break out due to natural cause	Intensity 4: 500 - 1000 Intensity 5:1000 - 2500 to	Intensity 4 3	6	the stone structure.		dkK1		1	
	of fractures etc.	Intensity 6: > 2500 nOn 0O1	Intensity 5 4	Potot-	DETACHMENT OF	Detachment of a dark-colored crust tracing the stone surface	dkK <sub>2</sub> dkK <sub>3</sub>		1	
	Break out due to non-recognizable cause 00 7	) to 00_			STONE MATERIAL	Detachment of a dark-colored crust diK	Mass of detaching diK <sub>1</sub> Mass of detaching	Intensity 1 1	(19) - 1	
					Detachment of crusts with		material diKs	Intensity 2 2		
	DISCOLORATION / DEPOSITS	-	RATING OF DAMAGE		stone material sticking K	Detachment of a light-colored crust tracing the stone surface	Intensity 2: medium hkK <sub>2</sub>			
MAIN WEATHERING FORMS	INDIVIDUAL WEATHERING FORMS	INTENSITIES OF INDIVIDUAL	INTENSITIES OF THE WEATHERING ECOMMS		to the crust.	Detachment of a light-colored crust	20	Intensity 3 3	20	
DISCOLORATION	Coloration	Degree - change of color Dc1				changing the stone schace	hiK,		We shall be	
Alteration of the	Chromatic alteration / coloring due to chemical weathering of minerals (e.g. oxidation of iron of coloring matter or due to staining by	Intensity 1: Jow	Intensity 2 3			Detachment of a colored crust tracing the stone surface fkK	ficK <sub>2</sub>		LOW NOTATION AND	
original stone color.	Soiling by particles from the atmosphere	DC <sub>2</sub>		14			MS		1	
	Poorly adhesive, mainly grey to black pl 9	Mass of deposits pl2		8		FISSURES / DEFORMATION		RATING OF DAMAGE	2)	
	Soiling by particles from water Poorly adhesive, mainly grey to brown WI	or degree - covering of the surface	Intensity 1 1		MAIN WEATHERING FORMS	INDIVIDUAL WEATHERING FORMS	INTENSITIES OF INDIVIDUAL WEATHERING FORMS	THE WEATHERING FORMS	「「「「「「「「」」」」	
Dirt deposits on	deposits of dust, soil or mud particles. Soiling by droppings	Intensity 1: Jow Wl2 Intensity 2: high clu	Intensity 2 1		FISSURES	Fissures independent of stone structure	VL1			
the stone surface.	Deposits of droppings from birds, e.g. from sparrows.	glz		9	Individual fissures or	Individual fissures or systems of fissures independent of structural features such as bedding etc.	(length, width) of fissures VL2	Intensity 1 2		
	Solling due to anthropogenic impact	alı		the first way	systems of fissures	Fissures dependent on stone structure	Intensity 1:Jow number and small dimension	Intensity 2 3	22	
	Efferences	al <sub>2</sub>		and the second	constructional causes.	Individual fissures or systems of fissures dependent on structural features such as bedding etc.	22 Intensity 2:high number or large dimension tL <sub>2</sub>		Citra -	
LOOSE SALT DEPOSITS	Poorly adhesive deposits of sait aggregates on the stone surface.	degree - covering of the surface (Ee)	Intensity 1 1					· L)	CONCO SS	
Poorly adhesive deposits E	Subflorescences	Intensity 1: Jow Ef1	Intensity 2 2	CONTRACTOR OF		Detailed description				
	aggregates below the stone surface, e.g. in the zone of detachment of scales.	Ef2		() () ()	WEATHERI	NG of individual weathering phenomena	o no vis	ible	LINEAR DAMAGE INDEX	
	Dark-colored crust tracing the surface Compact deposit, grey- to black-colored, dkC	Degree - covering of the surface dkC1		What have the	FORMS	with quantification of their intensities	0 dama	ige	Dl <sub>in</sub> = 4 0) (B 1) (C 2) (D 3) (E 4) (F 5)	
	Mainly due to deposition of pollutants from the atmosphere.	Intensity 2: high dkC2			Definition	of damage categories,	1 very s	light	B (C 2) (D 3) (E 4) (F 5)	
	Dark-colored crust changing the surface Compact deposit, grey- to black-colored,	Thickness of the crust diC 1		1 martin	relating of weather	ing forms to damage categories	dama	ige	100 0 S Di <sub>in</sub> S 5	
CRUST	changing the morphology of the stone diC surface. Mainly due to deposition of of pollutants from the atmosphere. E.g. gypsum crust with impurities.	Intensity 1: high diC2	Intensity 1 2		DAMAG		2 slig dama	nt je	PROGRESSIVE DAMAGE INDEX DI <sub>prog</sub> =	
Strongly adhesive deposits on the	Light-colored crust tracing the surface	Degree - covering of the surface hkC1	Intensity 2 3	U Contraction of the second se	CATEGORI	ES weathering damage	mode	rate 1	100 ↓	
stone surface.	Compact deposit, light-colored, tracing the morphology of the stone surface. Mainly due to precipitation processes. Light-colored crusts of salt minerals.	Intensity 1: Jow Intensity 2: high hkC2		the second se			dama	ige	<u>B (C 4) (D 9) (E 16) (F 25)</u> 100	
	Light-colored crust changing the surface	Thickness of the crust hiC 1		20101	Definitio calculati	on of damage indices, on of damage indices	4 seve	re	0 S Dlyrreg S 5 A = Area (%) – damage category 0 B = Area (%) – damage category 1	
	Compact deposit, light-colored, changing the morphology of the stone surface. Mainly due to precipitation processes. Light-colored crusts of salt.	Intensity 1: Jow Intensity 2: high hiC2			from proport	tion of damage categories	dama	ige	c = Anta (%) - damage category 2 D = Anta (%) - damage category 3 E = Anta (%) - damage category 4 F = Anta (%) - damage category 5	
	Colored crust tracing the surface	Degree - covering of the surface fkC 1		(12)	DAMAGE	Conclusive	5 very se dama	evere	7 100 4	
	Compact deposit, colored, tracing the morphology of the stone surface. fkC Mainly due to precipation processes. E.g. colored crusts of salt minerals or	Intensity 1: Jow			INDICES	quantification and rating of damage	Damage cated	ories D	amage indices	
RIGI GOIGU	iron / manganese crusts. Microbiological colonization	Intensity 2: Aigh TKC <sub>2</sub>		HERIO MARCHI			Lunage outeg	-1100 D		
COLONIZATION	Colonization by microflora (fungi, algae, lichen) and bacteria. Biofilms. Bi	Degree - covering of the surface Intensity 1: /ow Bi2	Intensity 1 2	(3)	Ratin	g of damage			1.000	
Colonization by micro-	Colonization by higher plants Bh	Intensity 2: high Bh1	Intensity 2 3					B Fitzner Acade	mic Director	
	1. A. A. A. A. A.	Bh <sub>2</sub>		ARRAN AS TO BE TO			Geological In	stitute / RWTH A	achen University	
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