An Investigation of Material Changes Occurring within Mineral Collections

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SEAHA
EPSRC CENTRE FOR DOCTORAL TRAINING
SCIENCE AND ENGINEERING IN
ARTS HERITAGE AND ARCHAEOLOGY

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national museum cardiff
amgueddfa genedlaethol caerdydd

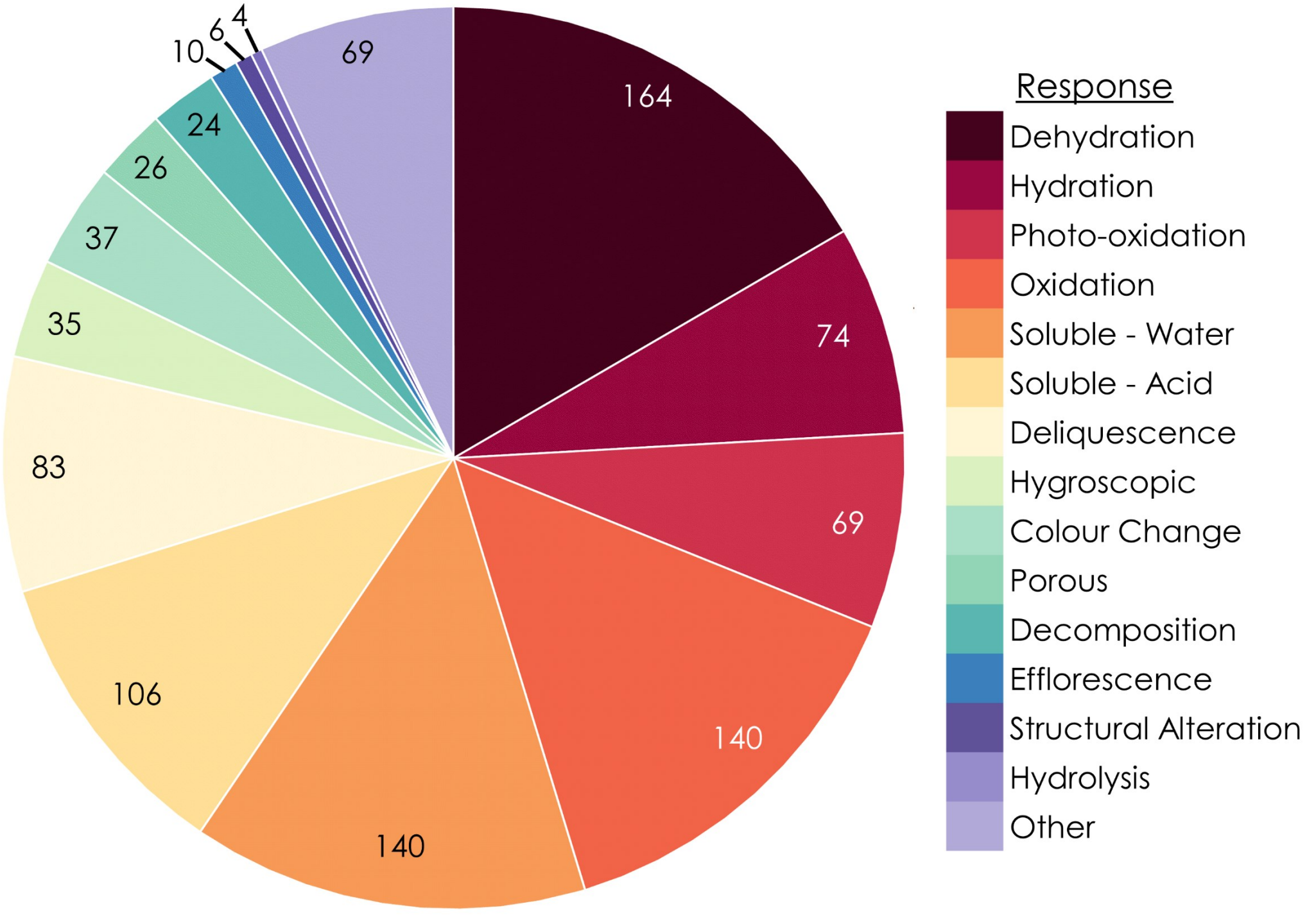
OR 3D
Digitise Dimension Design

BSRIA

the Mineral Susceptibility Database (MSD)

- Consolidates current* research from various scientific fields into one freely accessible location
- 987 entries
- 596 mineral species
  - 10% of IMA approved species**
- Effects of 4 Agents of Change
  - Improper temperature
  - Improper humidity
  - Light: UV-vis-IR
  - Pollutants

*up to 2020; ** as of Sep. 2023


164
74
69
140
140
106
83
35
37
26
24
10
6
4
69
Response
Dehydration
Hydration
Photo-oxidation
Oxidation
Soluble - Water
Soluble - Acid
Deliquescence
Hygroscopic
Colour Change
Porous
Decomposition
Efflorescence
Structural Alteration
Hydrolysis
Other

State Survey at OUMNH

Aim: Confirm alignment between literature & reality

- Agreement between experimental data & museum specimens

the Collection

- ~40,000 specimens
- ~12,300 unique species
- c.1650 – present
- T: 16–29°C, RH: 33–65%

the Survey

- 13,716 specimens
- 1,049 mineral species
- ALL mineral groups
- Completed in 181 hours over 69 days

the Deterioration Phenomena State Survey Method

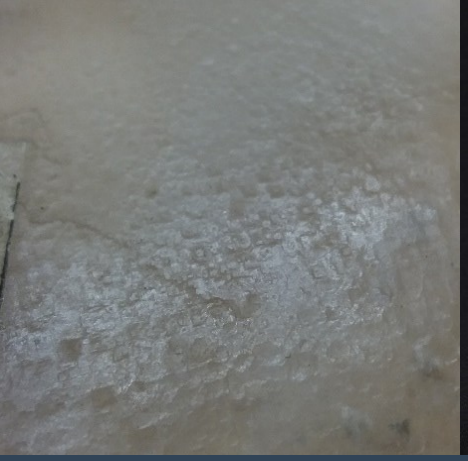
Dimple	Rounded	Corrosion	Tarnish	fflorescence	Powder	Crumbling	Flaking	Breakages	Cracks	Dull/Matte	Darker	Lighter	Opacity	olour Change
0	0	1	1	0	0	0	0	0	1	1	0	0	0	1
0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
0	0	1	0	0	0	0	0	0	1	1	0	0	0	1
0	0	0	1	0	0	1	0	1	1	0	0	0	0	0
0	0	0	1	0	0	0	0	0	1	1	1	0	0	1
0	0	0	1	0	0	1	0	1	1	1	0	0	0	1
0	0	1	1	0	0	0	0	0	0	0	1	0	0	1
0	0	0	1	0	0	0	0	0	1	1	0	0	0	0
0	0	0	1	0	0	0	0	0	1	0	0	0	0	0
0	0	0	1	0	0	0	0	0	0	0	1	0	0	1
0	0	1	1	0	0	0	0	0	0	0	0	0	0	1
0	0	0	1	1	0	0	0	0	1	0	0	0	0	1
0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
0	0	0	1	0	0	1	0	0	1	1	0	0	0	1
0	0	0	1	0	0	0	0	0	1	0	0	0	0	0
0	0	0	1	0	0	0	0	1	1	0	0	0	0	0
0	0	0	1	0	0	1	0	0	1	1	0	0	0	0
0	0	0	0	0	0	0	0	0	1	0	0	0	0	0

- Examine state objectively & quantitatively
  - View signs of change neutrally
- Quickly perform on whole or fraction of collection

Deterioration Phenomena (DP)

- Visually indicative of change to given collection
- Presence/absence only (1 / 0)
  - No determination of extent/severity
  - Increase speed, reduce variability, avoid assigning quantitative values to subjective perception
- Cause of change attributed during data analysis
  - Minimise distraction, interpretational bias, & attribution error

For further details see: Royce, K. 2024. *Journal of Natural Science Collections*, 12, 85-105.



Dimpled

Rounded

Corrosion

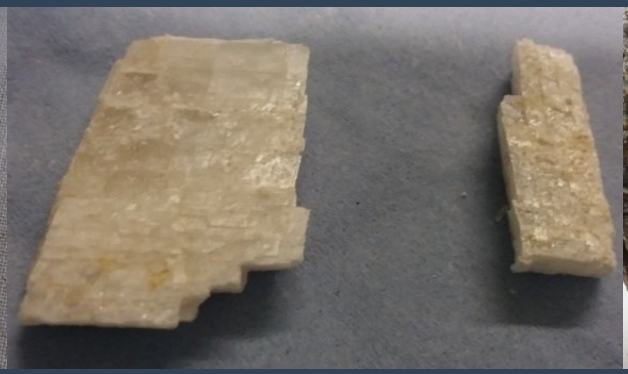
Tarnish

Efflorescence

Powder

Crumbling

Flaking



Breakages

Cracks

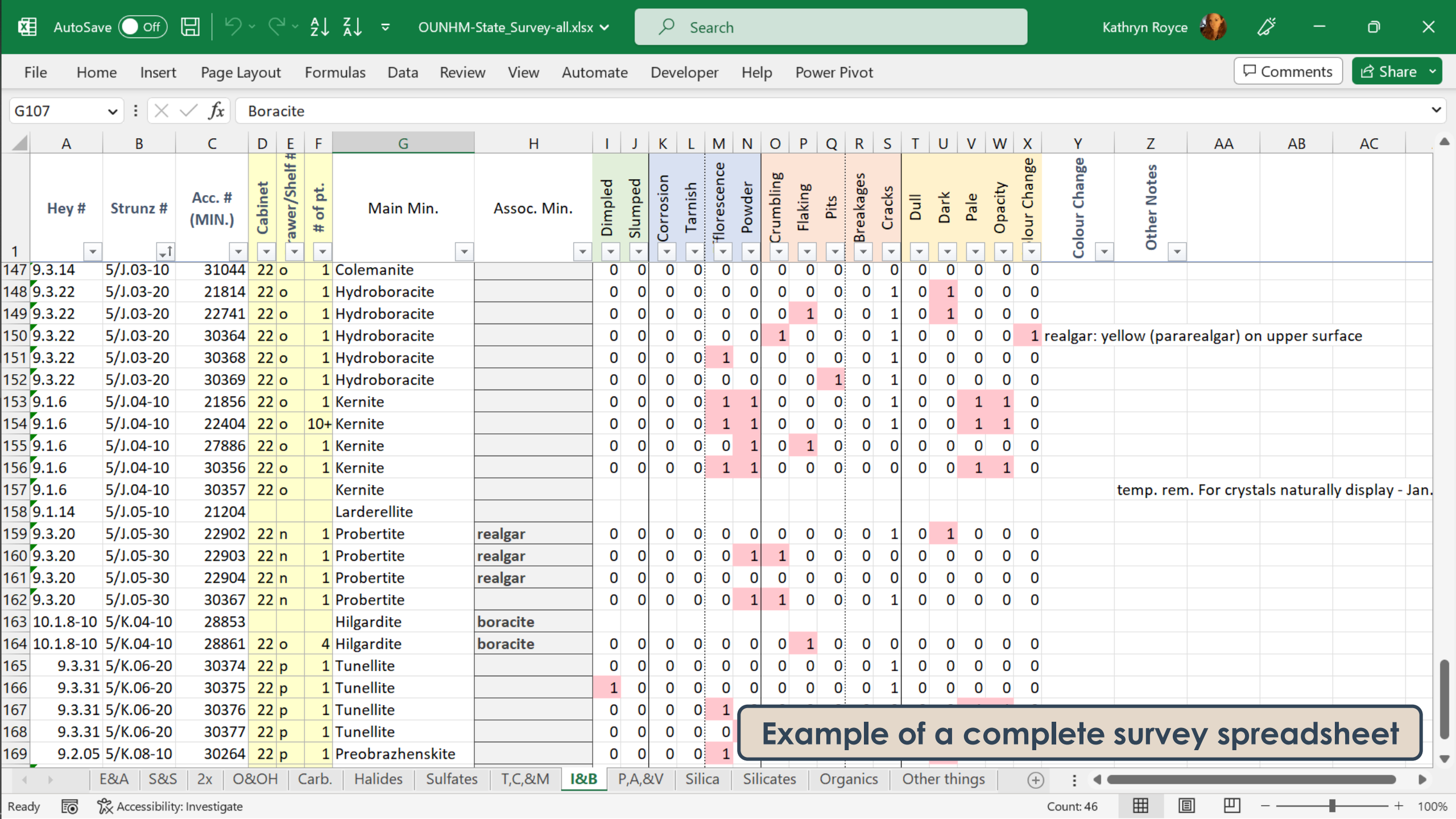
Dull

Dark

Pale

Opacity

Colour Change



	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA	AB	AC
1	Hey #	Strunz #	Acc. # (MIN.)	Cabinet	rawer/Shelf #	# of pt.	Main Min.	Assoc. Min.	Dimpled	Slumped	Corrosion	Tarnish	florescence	Powder	Crumbling	Flaking	Pits	Breakages	Cracks	Dull	Dark	Pale	Opacity	lour Change	Colour Change	Other Notes			
147	9.3.14	5/J.03-10	31044	22	o	1	Colemanite		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0					
148	9.3.22	5/J.03-20	21814	22	o	1	Hydroboracite		0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0					
149	9.3.22	5/J.03-20	22741	22	o	1	Hydroboracite		0	0	0	0	0	0	0	1	0	0	1	0	1	0	0	0					
150	9.3.22	5/J.03-20	30364	22	o	1	Hydroboracite		0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	1	realgar: yellow (pararealgar) on upper surface				
151	9.3.22	5/J.03-20	30368	22	o	1	Hydroboracite		0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0					
152	9.3.22	5/J.03-20	30369	22	o	1	Hydroboracite		0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0					
153	9.1.6	5/J.04-10	21856	22	o	1	Kernite		0	0	0	0	1	1	0	0	0	0	1	0	0	1	1	0					
154	9.1.6	5/J.04-10	22404	22	o	10+	Kernite		0	0	0	0	1	1	0	0	0	0	1	0	0	1	1	0					
155	9.1.6	5/J.04-10	27886	22	o	1	Kernite		0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0					
156	9.1.6	5/J.04-10	30356	22	o	1	Kernite		0	0	0	0	1	1	0	0	0	0	0	0	0	1	1	0					
157	9.1.6	5/J.04-10	30357	22	o		Kernite																			temp. rem. For crystals naturally display - Jan.			
158	9.1.14	5/J.05-10	21204				Larderellite																						
159	9.3.20	5/J.05-30	22902	22	n	1	Probertite	realgar	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0					
160	9.3.20	5/J.05-30	22903	22	n	1	Probertite	realgar	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0					
161	9.3.20	5/J.05-30	22904	22	n	1	Probertite	realgar	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0					
162	9.3.20	5/J.05-30	30367	22	n	1	Probertite		0	0	0	0	0	1	1	0	0	0	1	0	0	0	0	0					
163	10.1.8-10	5/K.04-10	28853				Hilgardite	boracite																					
164	10.1.8-10	5/K.04-10	28861	22	o	4	Hilgardite	boracite	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0					
165	9.3.31	5/K.06-20	30374	22	p	1	Tunellite		0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0					
166	9.3.31	5/K.06-20	30375	22	p	1	Tunellite		1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0					
167	9.3.31	5/K.06-20	30376	22	p	1	Tunellite		0	0	0	0	1																
168	9.3.31	5/K.06-20	30377	22	p	1	Tunellite		0	0	0	0	0																
169	9.2.05	5/K.08-10	30264	22	p	1	Preobrazhenskite		0	0	0	0	1																

Percent DP (%DP) Patterns

	Average														Type of deterioration	
MINERAL	**% Dim**	**% Tarn**	**% Efflo**	**% Pow**	**% Crus**	**% Flak**	**% Pits**	**% Brea**	**% Crac**	**% Dull**	**% Dark**	**% Pale**	**% Opa**	**% Colo**	**1st Order**	**2nd Order**
Vonsenite	0%	0%	0%	0%	0%	0%	0%	0%	100%	25%	0%	0%	0%	0%	Physical forces	Surfical Oxidation
Fluoborite	0%	0%	67%	0%	0%	0%	0%	0%	67%	0%	0%	0%	0%	0%	Efflorescence	—
Berborite	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	—	—
Wightmanite	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	—	—
Canavesite	0%	100%	0%	0%	0%	0%	0%	0%	100%	0%	0%	0%	0%	100%	Surfical Oxidation	—
Sulfoborite	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	—	—
Szaibelyite	0%	0%	50%	0%	0%	0%	0%	0%	50%	0%	0%	50%	0%	0%	Efflorescence	—
Sussexite	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	—	—
Pinnoite	0%	0%	0%	100%	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%	Physical forces	—
Kurnakovite	0%	0%	100%	100%	0%	0%	0%	0%	50%	0%	0%	100%	100%	0%	Efflorescence	—
Inderite	0%	0%	100%	100%	0%	0%	0%	0%	100%	0%	0%	100%	100%	0%	Efflorescence	—
Inderborite	0%	0%	0%	100%	0%	0%	0%	0%	100%	0%	0%	0%	0%	33%	Physical forces	—
Meyerhofferite	0%	0%	0%	100%	75%	0%	0%	50%	25%	0%	0%	0%	0%	0%	Physical forces	—
Inyoite	0%	0%	0%	100%	0%	0%	0%	100%	0%	0%	100%	0%	0%	0%	Physical forces	—
Tincalconite	0%	0%	0%	100%	100%	0%	0%	0%	0%	0%	0%	0%	0%	0%	Physical forces	—
Borax	0%	0%	0%	100%	33%	17%	0%	0%	17%	0%	0%	0%	0%	67%		
Boracite	29%	0%	5%	0%	0%	0%	0%	3%	8%	0%	34%	0%	0%	0%	—	surface wetting
Ulexite	0%	0%	7%	64%	36%	7%	0%	0%	21%	0%	64%	7%	0%	14%		
Colemanite	29%	0%	18%	12%	6%	6%	0%	12%	35%	0%	12%	0%	0%	0%	—	surface wetting
Hydroboracite	0%	0%	20%	0%	20%	20%	20%	0%	100%	0%	40%	0%	0%	20%	Physical forces	—
Kernite	0%	0%	75%	100%	0%	25%	0%	0%	50%	0%	0%	75%	75%	0%	Dehydration	—
Probertite	0%	0%	0%	50%	50%	0%	0%	0%	50%	0%	25%	0%	0%	0%	Physical forces	—
Hilgardite	0%	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%	0%	0%	0%	Physical forces	—
Tunellite	25%	0%	25%	25%	0%	0%	0%	0%	50%	0%	0%	25%	25%	0%	Physical forces	surface wetting
Preobrazhenskite	0%	0%	100%	0%	0%	0%	0%	0%	100%	0%	100%	0%	0%	0%	Efflorescence	
Braitschite-(Ce)	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	—	—
Hambergite	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	—	—
Total	13%	1%	16%	29%	11%	4%	1%	4%	34%	1%	22%	10%	7%	7%	—	Physical forces

1st order > 50%

2nd order < 50%

Conditional Formatting Key	
75–100%	Red
50–74%	Orange
25–49%	Yellow
0–24%	N/A

%DP Patterns Example: Pyrite

DP	%DP
Corrosion	11%
Tarnish	86%
Efflorescence	23%
Powder	7%
Crumbling	21%
Flaking	5%
Breakages	9%
Cracks	56%
Dull	78%
Dark	57%
Colour Change	33%
# of Specimens	1,274*

1st Order: Surficial Oxidation
↳ Dull & Tarnish > 75%

2nd Order: Oxidation at Depth
↳ Signs of Pyrite Decay < 25%

- Efflorescence
- Powder
- Crumbling
- Breakages

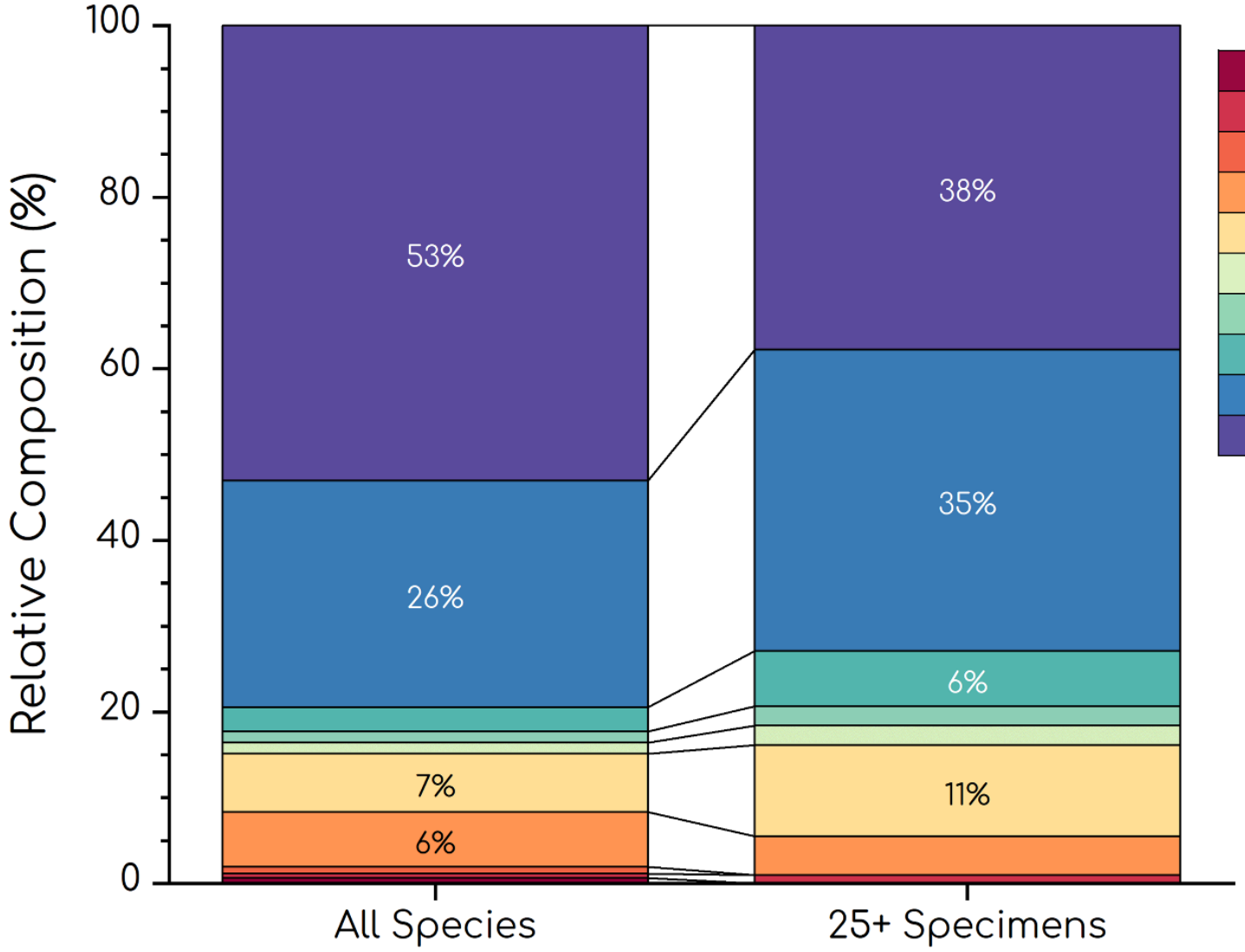
* Data from cross-museum pyrite survey, not just OUMNH

Predominant Reaction Type = Physical Forces

- Similar %DP patterning across most mineral groups
- 2nd order = physical forces => cracks in 26-46% of specimens

Mineral Group	Elements & Alloys	Sulfides & Sulfosalts	Halides	Oxides & Hydroxides	Tungstates, Chromates, & Molybdates	Carbonates	Iodates & Borates	Sulfates	Phosphates, Arsenates, & Vanadates	Silica	Ortho	Soro	Ring	Chain	Sheet	Framework	Total
Dimpled	0%	0%	18%	2%	1%	3%	13%	7%	1%	8%	5%	0%	2%	1%	1%	1%	4%
Rounded	0%	0%	9%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	1%
Corrosion	9%	15%	4%	1%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	2%
Tarnish	39%	50%	7%	18%	9%	1%	1%	2%	3%	5%	1%	2%	1%	1%	1%	0%	9%
Efflorescence	2%	5%	15%	5%	11%	18%	16%	25%	18%	1%	2%	1%	1%	1%	2%	1%	8%
Powder	2%	6%	3%	7%	3%	5%	29%	20%	9%	5%	2%	2%	4%	5%	5%	3%	7%
Crumbling	9%	16%	15%	11%	14%	24%	11%	27%	17%	9%	5%	10%	12%	6%	8%	7%	13%
Flaking	3%	4%	1%	3%	1%	0%	4%	3%	3%	0%	4%	3%	6%	10%	19%	2%	4%
Breakages	4%	4%	2%	5%	8%	5%	4%	9%	4%	7%	3%	5%	5%	5%	6%	4%	5%
Cracks	7%	42%	20%	36%	31%	41%	34%	41%	43%	26%	27%	36%	31%	36%	46%	27%	33%
Dull	40%	56%	10%	12%	14%	3%	1%	1%	1%	4%	1%	1%	1%	1%	2%	0%	9%
Dark	33%	25%	14%	11%	18%	24%	22%	22%	10%	14%	5%	5%	4%	9%	8%	16%	15%
Pale	1%	2%	1%	0%	1%	3%	10%	7%	2%	0%	0%	0%	0%	0%	1%	0%	2%
Opacity	0%	0%	6%	0%	0%	1%	7%	7%	0%	3%	2%	5%	3%	1%	1%	0%	2%
Colour Change	13%	22%	4%	6%	2%	3%	7%	6%	1%	1%	1%	1%	0%	0%	0%	1%	4%
ADP	2	2	1	1	1	1	2	2	1	1	1	1	1	1	1	1	1
1st Order	—	surficial oxidation	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
2nd Order	surficial oxidatio	physical forces	dehydration	physical forces													
# of specimens	996	2449	564	1523	270	831	136	521	1315	220	855	440	345	723	795	1277	13260
# of species	23	115	43	127	15	62	34	78	178	2	61	57	28	77	75	71	1046

Predominant Reaction Type = Physical Forces



Reaction Type	All Species	25+ Specimens
Colour Change	1%	0%
Surface Wetting	1%	1%
Dehydration	1%	0%
Efflorescence	6%	5%
Surficial Oxidation	7%	11%
Oxidation at Depth	1%	2%
Pollutant-Induced Deterioration	1%	2%
Pollutant Deposition	3%	6%
Physical Forces	26%	35%
None	53%	38%

- ~1/3 of all specimens exhibit cracking
- All other DP occur in $< \frac{1}{5}$ of surveyed specimens

Sources for Physical Forces

- Improper handling & accidents
- Inherent fragility or friability of specimen

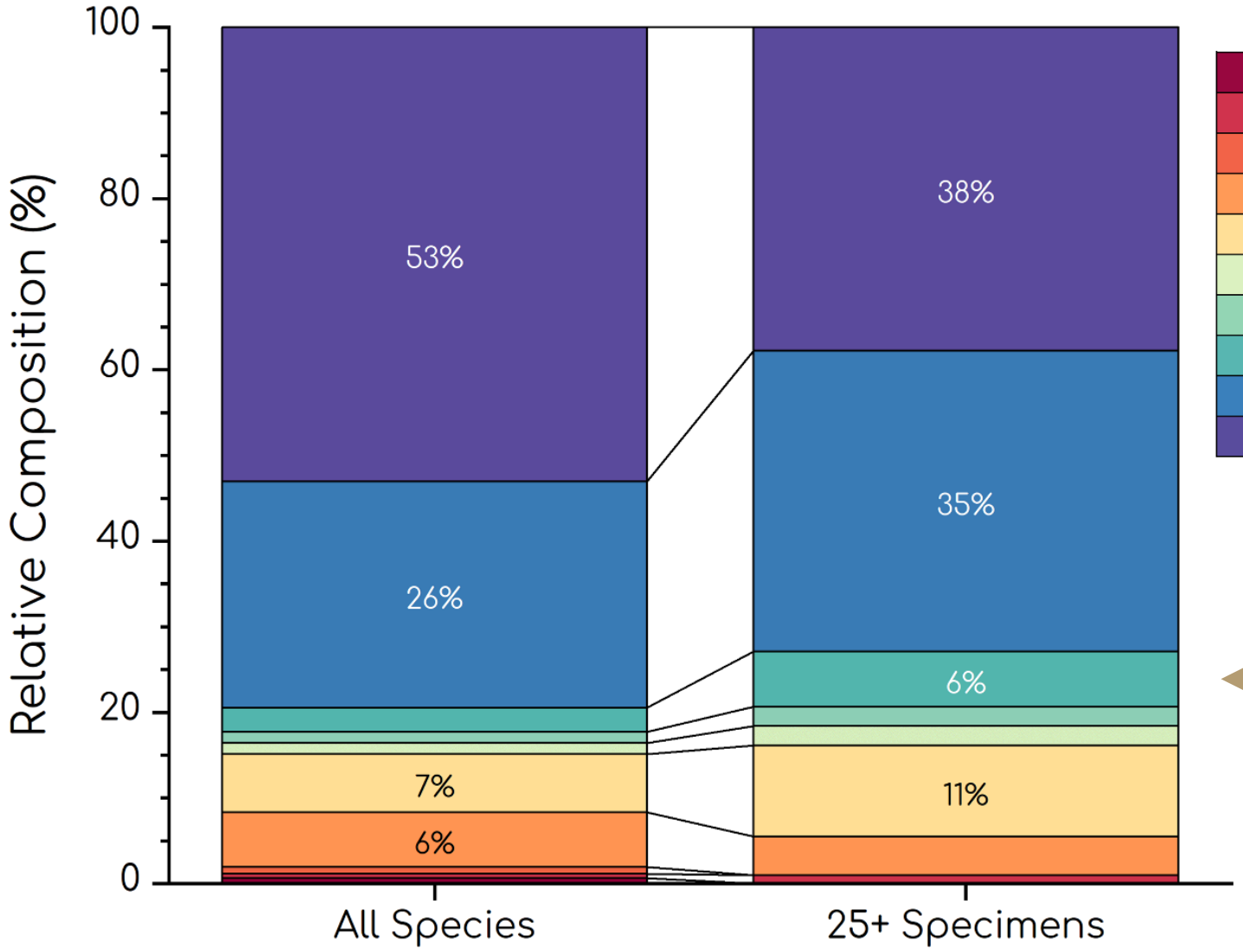
- In-drawer movements:
  jumping, rocking, rolling, sliding
  - Rough drawer movement
    - Doesn't slide easily
    - Jerky movements to open/shut
  - Drawers not trayed out => trays slide
  - Inadequate support for specimens
    - Too large unit trays
  - Specimen placed on faces prone to movement

Easy Fixes for Physical Forces

- Training re. handling & supporting specimens
- Awareness of specimen's properties

- Repair drawers
- Oil/sand runners
- Ensure drawers supported when opened
- Fully tray-out drawers or line with non-slip material
- Place specimens on face that produces least movement
- Provide support for fragile & movement-prone specimens

What's with the pollutant deposition?



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	Pollutant Deposition	3%	6%
	Physical Forces	26%	35%
	None	53%	38%

What is it though?

- Dark & soot-like
- On older specimens (~ pre-1980) across ALL mineral groups

- Unknown composition
- Likely combination of:
  - Dust
  - Outdoor pollutants (e.g. automotive exhaust, coal)
  - Cigarette smoke

- Could be affecting specimen deterioration
  - Cleaning required to assess impact

What is it though?

Conclusions

- Survey confirmed solubility & changes in hydration/oxidation state are indeed prevalent in museum collections
  - Not overrepresented in MSD
- Collections may contain more species susceptible to other reaction types (e.g., photo-induced)
  - Nature of museum storage makes it difficult to identify
- Physical forces is predominate reaction type
  - Can affect every specimen
  - Need to ensure proper mitigation

Thank you for listening!

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Questions?

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http://mineralcare.web.ox.ac.uk