Rock anchor corrosion

UIAA Safety Commission
ICAR meeting, Chamonix 2018
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UIAA ?

Union

Internationale

des **A**ssociations

d'**A**lpinisme

UIAA Safety Commission mission

To support climbers and mountaineers

in their goal of managing the inherent risks of these activities.

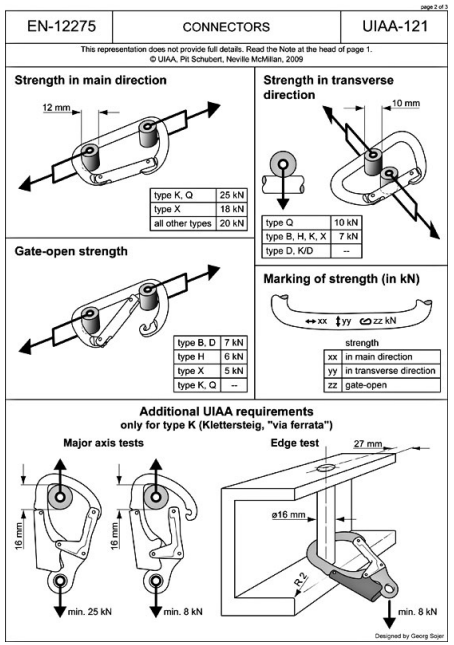
→ by establishing equipment standards

→ with recommendations for correct use

UIAA Safety Standards

On climbing technical equipment only:

- ropes
- slings
- harnesses
- EAS via-ferrata
- carabiners
- rock anchors
- nuts and friends
- pitons
- ice screws
- ice tools
- helmets
- …



→ https://www.theuiaa.org/safety-standards/

UIAA Safety Standards

Certified equipment database…

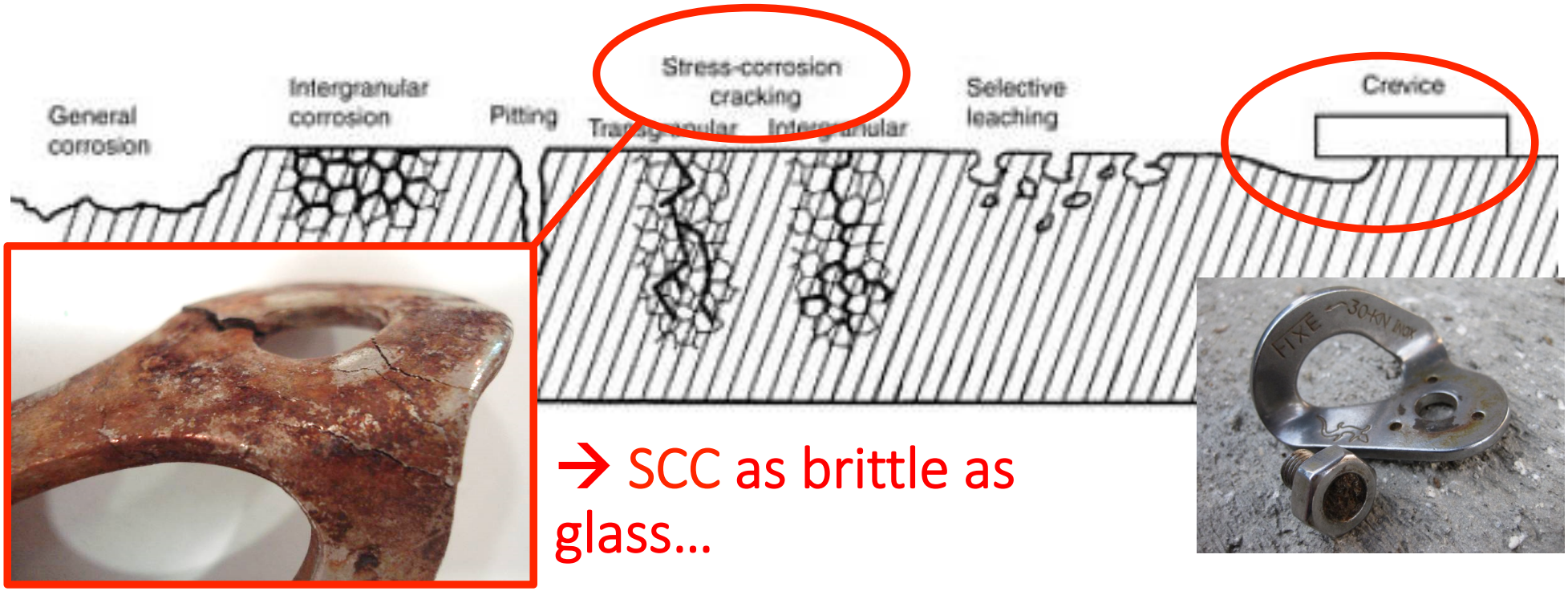
→ https://www.theuiaa.org/safety-standards/certified-equipment/

UIAA Safety Commission

Recall database…

→ https://www.theuiaa.org/safety-standards/recalls/

one corrosion?
NO: multiple corrosions

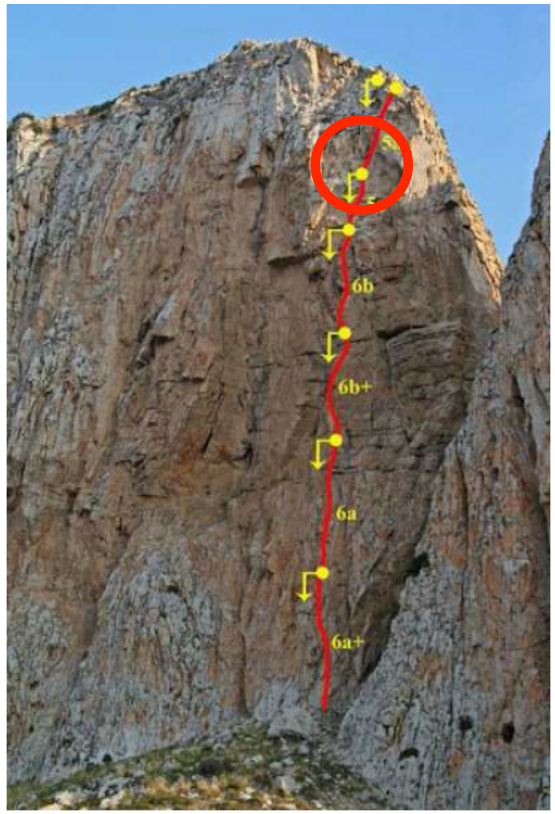


→ SCC as brittle as glass…

SCC Example: belay bolt rupture

- Sicilia: San Vito lo Capo
- Route: La collina dei conigli

- the lower bolt of the belay broke when one mountain guide was abseiling down
- less than 100kg !
- bolted 7 years ago
- the same belay was used two days before



What does the UIAA do?

- first analyses
- warning release
  - please inform us and collect samples ☺
- laboratory tests: materials, anchors and chemistry
- long term tests in-situ

Systematic testing

16,8 KN

1,1 KN

0KN

0KN

Recap of 2009/ 2010: samplings in different places (130 bolts)

2,5KN

2,2KN

28KN

SCC contribution factors

FACTORS	MOST CRITICAL ONE	remarks
ENVIRONMENTAL CHARACTERISTICS		
concentration of chloride	magnesium chloride calcium chloride sodium chloride	Chloride deposits containing salts with high solubility can be formed.
temperature	NOT any cut-off/"safe" level, but above 30°C is worse	SCC could start at 20°C, a higher temperature increase the cracking speed; the temperature of a bolt in the sun can be significantly higher than the ambient air temperature.
humidity	low relative humidity, between 20% and 70%	RH close to the deliquescence point of the chloride solution poses a significant danger of SCC.
location – coastal / wind from the sea	next to the sea up to 30 km from the coast?	There is no clear limit; winds from the sea with significant salt concentration can travel hundreds of km inland.
washed by rain or not	not washed by rain	The absence of washing allows the chloride to concentrate locally on anchors.
rock type	limestone or dolomite	Probably because of its high calcium and magnesium content.

Failures to Date: data from analyses

Region/Country	SCC	Other types of corrosion
Thailand Krabi	316(?), 304	304, 316
Hong Kong	304	304
Taiwan (Long Dong)	304, 316(?)	304, 316
Australia	304	304, 410
Greece (Kalymnos)	??	304, 316(?)
Malta	304	
Italy (Sardinia)	304	304
Croatia	316(?)	
Portugal (Coastal & Inland)	304	304
Spain	304	304
Germany: outside climbing wall	304?	
Cayman Brac	304	
Hawaii	304	
South Africa (Cape Region)	304	
Madagascar (interior)	304	
Brazil (Rio region)	304	304

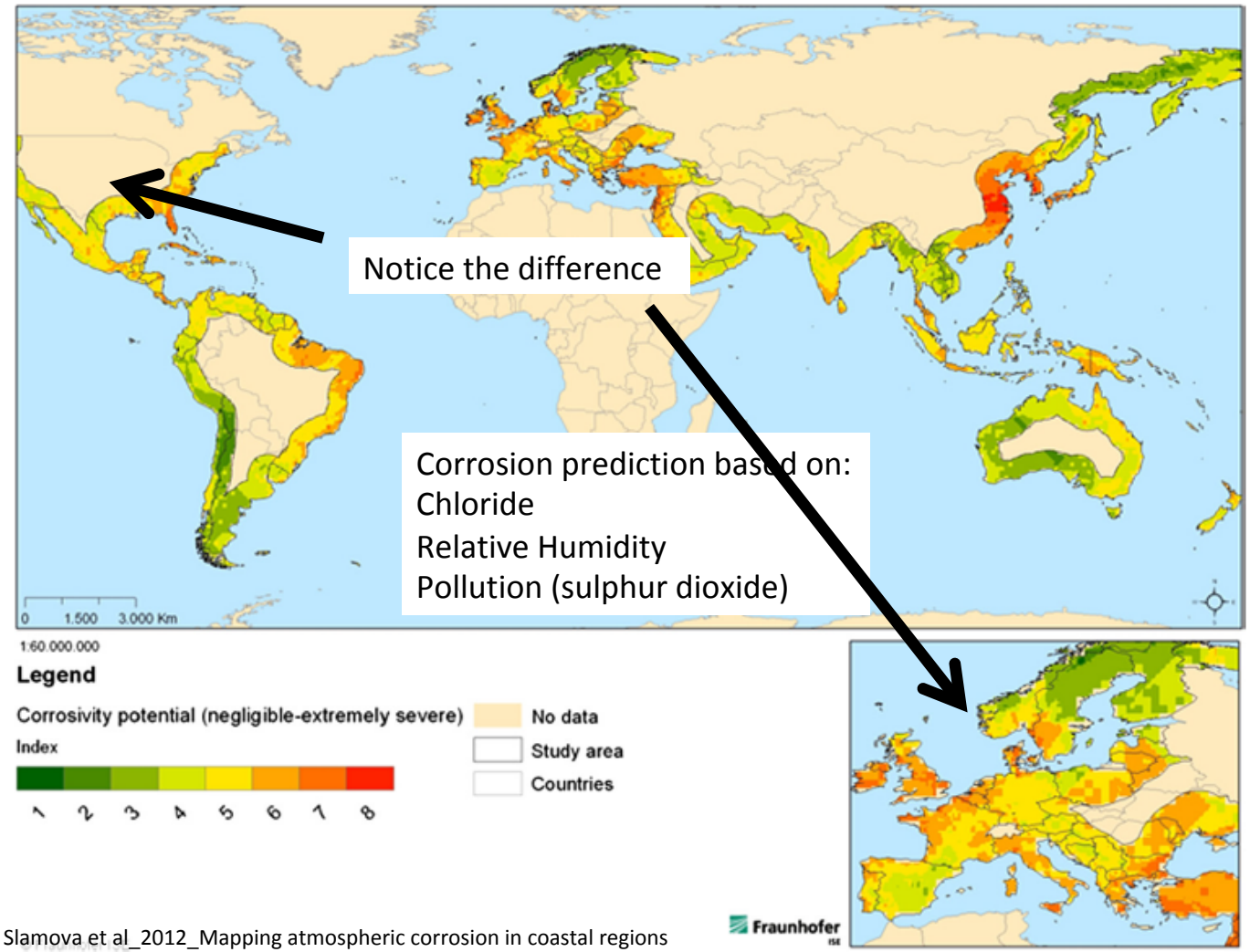
There are more, this is just some of them

SCC situation around the world

- 2-3 MILLION climbing anchors
- Installed in HUGE variety of locations:

  hot/cold, wet/dry, high altitude, sheltered/exposed, rural/urban
- We KNOW SCC is **possible**:

  high stresses, chloride, susceptible materials
- But of 3 million anchors we see very few failures, although enough to cause a danger



Slamova et al_2012_Mapping atmospheric corrosion in coastal regions

SCC depends on DESIGN as much as MATERIAL

Fig. 14 – Left: Crack on the eye of P-type anchor, initiated from a crevice between anchor and rock; Center: failed TCE bolt with almost completely corroded fracture surface; Right: failed bolt with cracked nut. Arrows show the SCC initiation sites.

Welds have a BIG effect

Fig. 16 - Original (top) and failed (bottom) P-type anchors from Taiwan. Left: forged; right: welded.

Many manufacturers don’t always use what they SAY they use

Fig. 15 - Failed quicklink made of low quality SS with false designation (sample P15).

Tests in laboratories

- pH swabs to test local environment
- Na, Ca, Mg, Chloride levels tested

  with the complete anchors installed in a block of stone

- Sulphur reducing bacteria presence suspected

Environmental exposure tests in Thailand

- Long term exposure tests, anchors in natural environment
- Not climbed on
- Inspected yearly
- Anchors donated: Petzl, Austrialpin, Bolt Products, Fixe

January 2014

500 anchors installed in 45 “clusters”

(each cluster same environment)

Titanium Grade 2 glue-ins (P-bolt & U-bolt)

6Mo hangers and expansion bolts

Duplex 2205 glue-ins

316 glue-ins (P-bolt & U-bolt) and hangers/ expansion bolts

304 hangers/expansion bolts

Environmental Exposure Tests

Jan 2017 (18 months)

- No SCC Failures
- 304 corrosion pitting more
- More 316 is pitting
- Duplex 2205 pitting
- 304 and 316 more advanced crevice corrosion
- 6Mo & Titanium no corrosion

Master thesis:
FAILURE ANALYSIS RESULTS AND DISCUSSION

Tab. 9 - Material overview of single parts of anchor systems and observed corrosion attack.

Material		Total	No corrosion	General corrosion or pitting	TG SCC	IG cracking
304	nut	36	-	28	8	-
	TCE bolt	46	-	12	34	-
	hanger	8	-	8	-	-
	P-bolt	11	-	-	11	-
	other	7	-	4	2	1
321		1	-	1	-	-
302HQ		3	-	3	-	-
17-7 PH		4	-	2	2	-
316		4	2	2	-	-
low Mo 316		2	-	-	-	2
low quality SS		2	-	-	2	-
410		3	-	1	2	-

Master thesis conclusion

- Failures of **AISI 304 and similar** anchors due to SCC, installed in various seaside locations.
- Intergranular cracking due to improper welding or material treatment was also identified.
- **No clear ASCC failure of AISI 316 SS was observed among the few obtained samples.**
- AISI 316 SS members have to be replaced if formation of red corrosion products on the member surface is observed. If cracking occurs, there is no significant difference in crack propagation rate between AISI 316 and 304 SS.

- **Anchor classification based solely on declared material cannot be recommended as a safe procedure** because of the following issues:
  - counterfeit SS grades,
  - imperfect material quality control (e.g. low Mo content),
  - improper heat treatment,
  - welding defects.

My recommendations

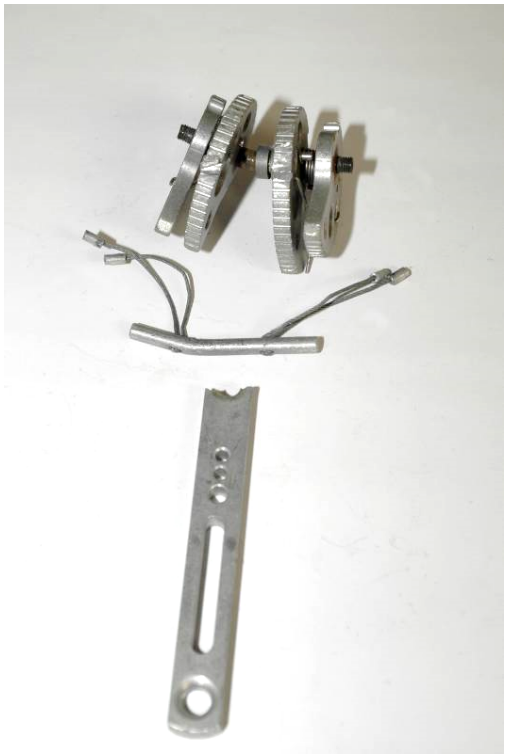
- Ask local climbers/bolters
- Pay attention to the visual aspect of each bolt:
  - crack
  - rust color (sometimes)
  - different colors: e.g. different materials ☹

→even if SCC is not really visible…

→hammering could be an inspection method
(even if it damage the anchors for the future)

→if any doubt: double with other protection:
→put new anchor(s)
→use slings, nuts, friends,… for redundancy

THANK YOU FOR YOUR ATTENTION ☺



Please contact me for any question:

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