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Soil and Bedrock Abrasivity Assessment for HDD

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Subsurface Characterization

- For HDD, normally consists of sampled test borings, maybe geophysics
- Lab Testing
  - Soil: Gradation, Strength
  - Rock: Strength, Rock Type

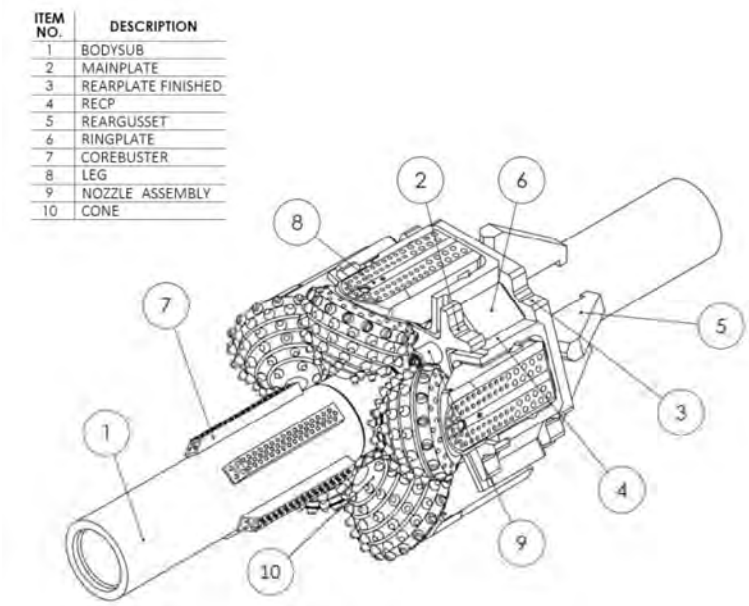
- Primary focus
  - Fracout risk
  - Pull force assessment, pipe stability
  - Overall geometry
  - Rock vs soil

- Most characterization programs do not assess abrasivity
- Occurrence of downhole tooling failure, catastrophic or through rapid degradation (beyond normal wear) top 3 contributors to schedule overrun*

***Osbak et al., 2012**

Abrasivity

- “abrasion” refers to loss of material from a surface by hard particles or protuberances on a counter surface
- Rotation and movement of the drill tool against the face and sidewall of the bore may result in <u>primary abrasion</u> of the portion of the drill tool intended to be in direct contact with the ground

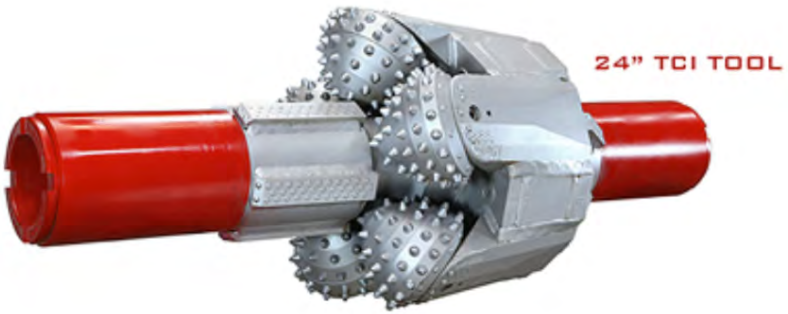


Abrasivity

- Wear of uphole, surface equipment by drill fluid carrying abrasive particles is <u>secondary abrasion</u>

The Risk in $$

- Tri cone bit, TCI 6.5” - $4,000
- 15” TCI reamer - $13,000
- 20” TCI reamer - $17,000
- 24” TCI split bit reamer - $49,000
- 24” TCI reamer - $48,000
- 36” TCI reamer - $60,000
- 48” TCI reamer - $85,000



Also consider cost of lowered efficiency, time to retrieve and replace downhole tooling

Subsurface Characterization

- Generally assume that the Contractor is responsible for tool wear, BUT……what if this requires extensive retooling, impacts schedule?
- Contractor: "Should I have expected this?"
- How do we test soil for abrasivity?
  - Soil Abrasion Test (SAT™)
  - Penn State Soil Abrasion Index (PSAI)
  - (neither that common)
- How do we test bedrock for abrasivity?
  - CERCHAR
  - Petrographic analysis – quartz content

Are there common indicators of abrasivity, if lab data not available?

Mineral Hardness, Soil and Rock

- Hardness based on Moh's relative scale

Moh's Hardness	Mineral	Drill Tool Component
10	Diamond	
9	Corundum	Tungsten carbide; 8.5-9
8	Topaz	Hardened Steel; 7-8 Tungsten; 7.5
7	Quartz, Garnet	
6.5	Plagioclase Feldspar	
6	Orthoclase Feldspar, Magnetite	
5.5	Amphibole (Hornblende)	Steel; 4 - 5.5, Cobalt; 5
5	Apatite	
4	Flourite, Dolomite	
3	Calcite	
2	Gypsum	
1	Talc	

Abrasion and wear rate increase significantly when the mineral hardness exceeds about 20% of the drill tool component

Mineral Hardness

- BUT needs to be hard and TOUGH
- (resistant to breaking down under stress)

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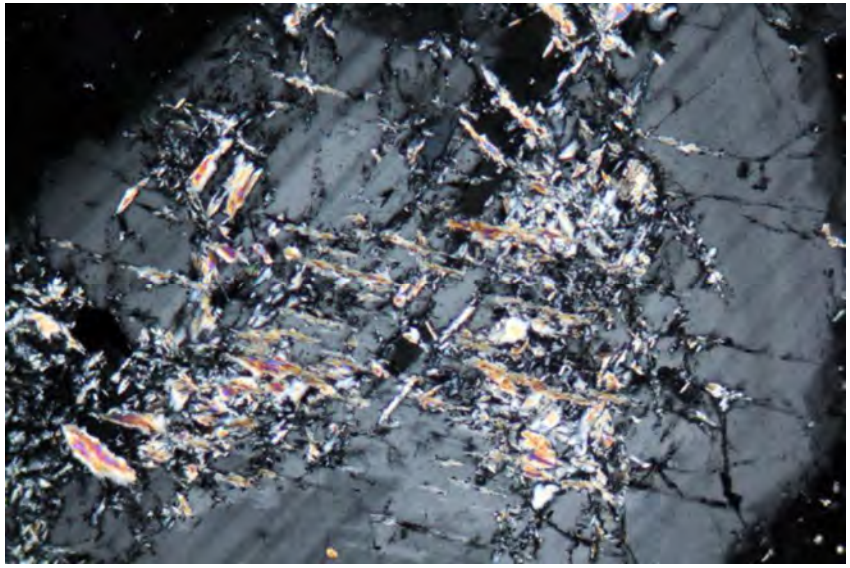
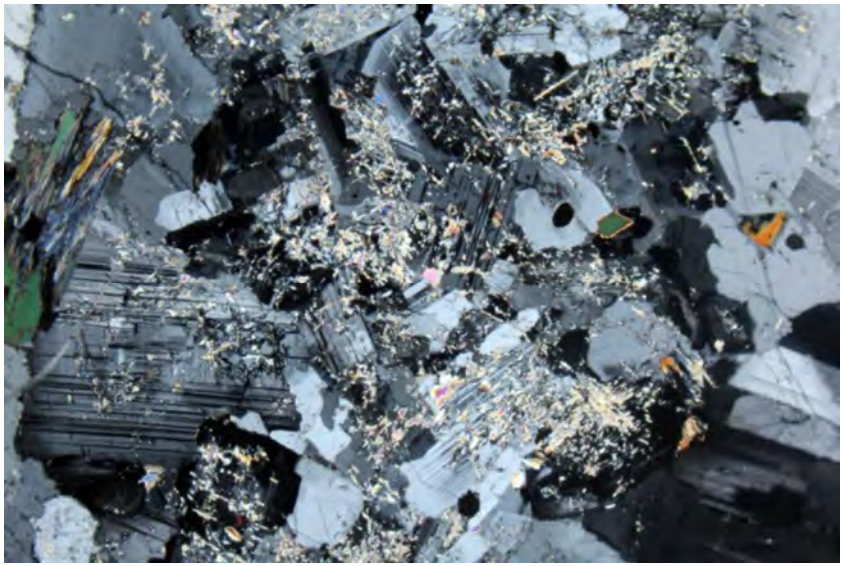
Mineral Hardness

- Example: Feldspar (plagioclase, orthoclase, etc., exhibits pervasive cleavage and weathering); poor toughness





Microphotographs courtesy www.alexstrekeisen.it

Mineral Hardness

- Example: Quartz. Good toughness. No cleavage, no weathering product.

www.jsjgeology.com

www.spec2000.net

Primary Abrasivity, Soil

Grain size: Sand and gravel-sized materials tend to be more abrasive than fine grained materials.

- Clay sized materials, even with high hardness, generally present low risk of abrasivity
- Addition of fines to corase materials reduces abrasivity

Density: Increasing density, presence of cementation increases abrasive potential

Shape: Abrasivity increases with decreased sphericity and decreased roundness

These criteria can be assessed with readily available information

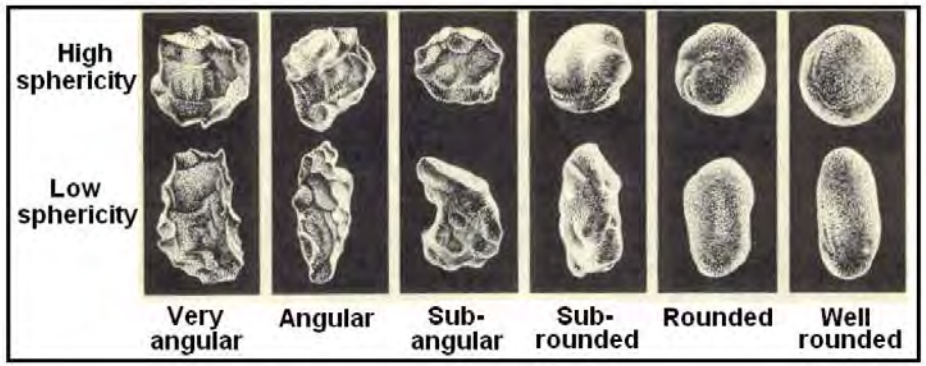
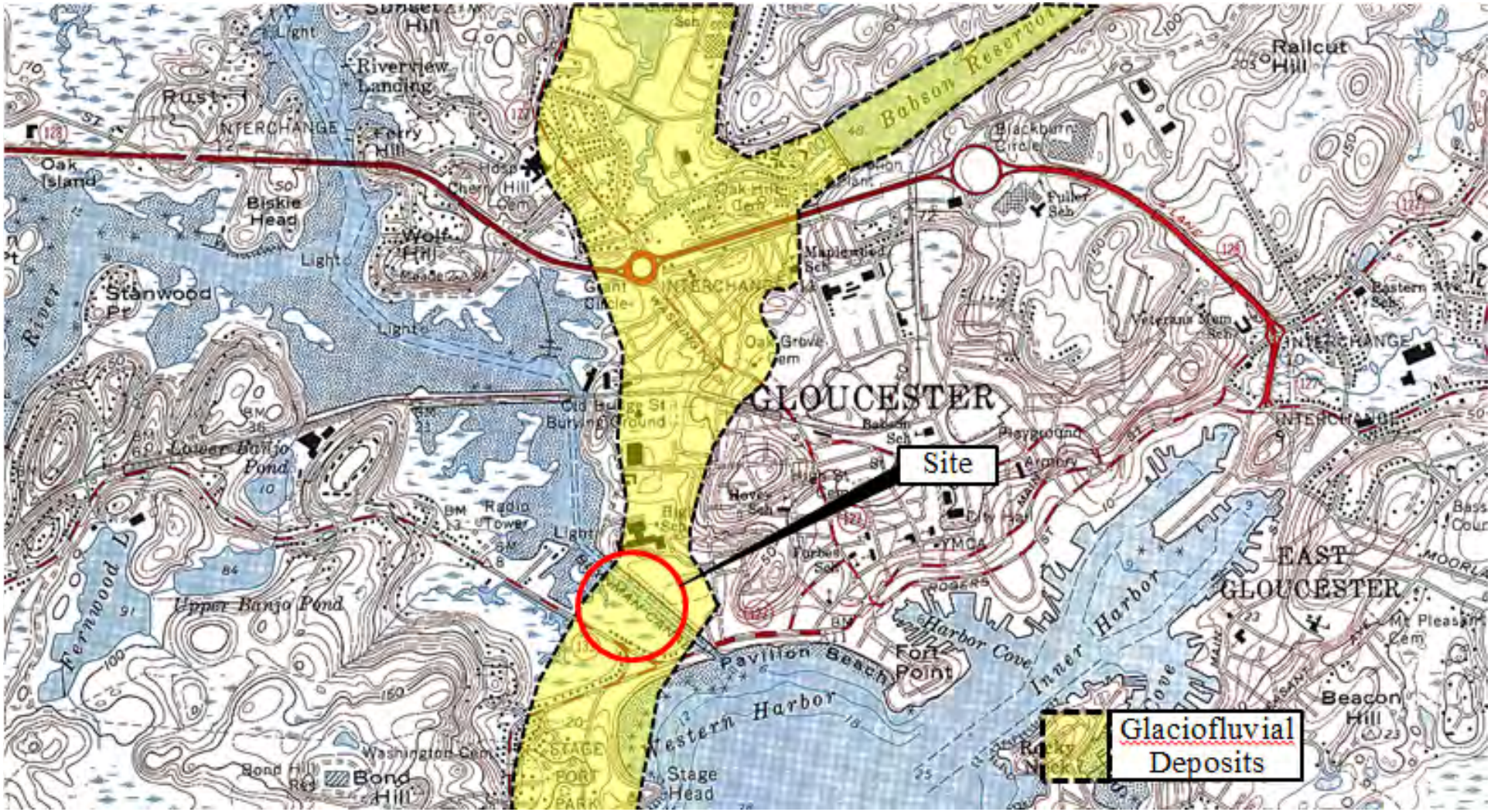


Table 2. Qualification of Soil Abrasivity

Parameter	**Range**					
Dominant Grain Size (USCS Code)	**Gravel (GP, GM), Cobbles**	**Sand, Gravelly Sand (SP, SW)**		**Silty Sand, Gravel, Clayey Sand, Gravel) (SM, GM, SC, GC)**	**Silt (ML)**	**Clay (CH, CL)**
Score	25	20		15	3	-5
% Hard, Tough Minerals (Moh's Hardness >6)	>80		80-50	50-20	20-10	10-0
Score	50		40	30	20	10
Angularity	Very Angular	Angular	Sub Angular	Sub Rounded	Rounded	Well Rounded
Score	5		3	2	1	1
Sphericity	Low			High		
Score	5			2		
Density, Consistency	Very Dense, Well Cemented	Dense	Medium Dense	Loose	Very Loose	
Score	15	12	10	5	2	

Score	**100-80**	**79-60**	**59-40**	**39-20**	**<19**
Abrasive Potential	Very High	High	Medium	Low	Very Low
Considerations	Excessive tool wear, frequent tool replacements, repairs	Significant tool wear, occasional tool replacement	Tool wear "typical"; tool replacement not required		Little or no observable tool wear

Examples


Site
Glaciofluvial Deposits
GLOUCESTER
EAST GLOUCESTER
Babson Reservoir
Railcut Hill
Riverview Landing
Rust
INTERCHANGE
Ferry Hill
Oak Island
Biskie Head
Wolf Hill
Stanwood Pt
Lower Banjo Pond
Upper Banjo Pond
Radio Tower
Bond Hill
Washington Cem
Pavilion Beach
Fort Point
Harbor Cove
Inner Harbor
Western Harbor
Stage Head
Beacon Hill
Blackburn Circle
Fuller Sch
Maplewood Sch
Veterans Mem
Eastern Ave Sch
Babson Sch
Playground
Armory
High St
YMCA
Forbes Sch
Oak Grove Cem
Cherry Hill Cem
Mt Pleasant Cem
Bass Cour
Cid Burying Ground
Light

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- Source: Cape Ann Granite
- *Significant tool wear*

Comparison


Pleistocene
Providence
Goose Point
ALDRICH FIELD
STATE SCHOOL FOR DEAF
Hope Street High Sch.
DEXTER ASYLUM
PEMBROKE COLLEGE
BROWN UNIVERSITY
COURTHOUSE
WITHERBY PARK
LOCKWOOTTON PARK
WASHINGTON BRIDGE
POINT ST. BRIDGE
Twin Islands
India Point
Bold Point
Fox Point
Fort Hill
Qgm
Qkt6
Qkt4
Qkx
af
s
p
50'
60
70

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- Source: Rhode Island Formation,

  shale, siltstone, sandstone, conglomerate

- *Minor tool wear*

Primary Abrasivity, Bedrock

Crystal/grain size: Sand and gravel-sized materials tend to be more abrasive than fine grained materials.

- Clay sized materials, even with high hardness, generally present low risk of abrasivity
- Addition of fines to coarse materials reduces abrasivity

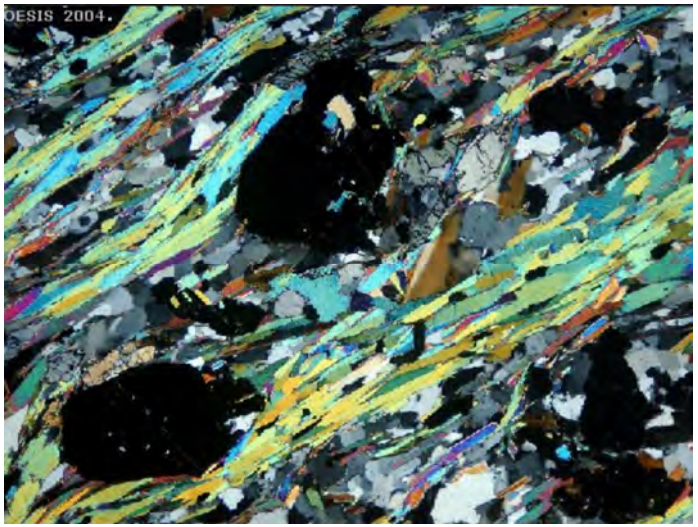
Strength: Increasing strength, cementation, recrystalization increases abrasive potential

Shape: Abrasivity increases with decreased sphericity and decreased roundness

Weathering: increased weathering decreases abrasivity (lab testing may not capture this)

Not Just the Quartz

- Most petrographic analyses only consider quartz
- Don’t identify or consider % of other abrasive minerals



Quartz – Garnet Schist

Amphibolite

In the absence of testing.....

Table 3. Qualification of Rock Mass Abrasivity

% Hard, Tough Minerals (Moh's Hardness >6)	>80	80-50	50 - 30	30 - 10	<10	
Score	60	50	35	20	10	
Compressive Strength, ksi	>35	35 - 20	20 - 12	12 - 7.5	7.5 - 2.5	<2.5
Score	30	20	15	10	5	2
Crystal/Grain/Clast Size	Coarse/gravel	Medium/sand			Fine/silt	Very fine/clay
Score	10	8			5	2
Degree of Weathering*	Fresh	Slight		Moderate		High
Score	0	-10		-25		-40

Score	100-80	79-60	59-40	39-20	<19
Abrasivity	Very High	High	Medium	Low	Very Low

* includes macroscopic and microscopic

Equivalent Cerchar Value	6 - 4	4 - 2	2 - 1	1 - 0.5	< 0.5

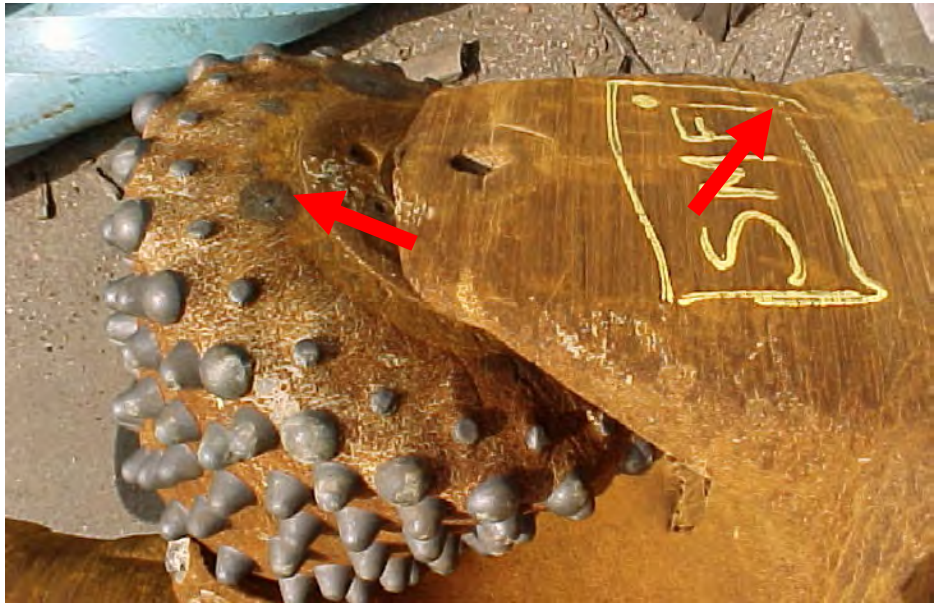
WORK IN PROGRESS

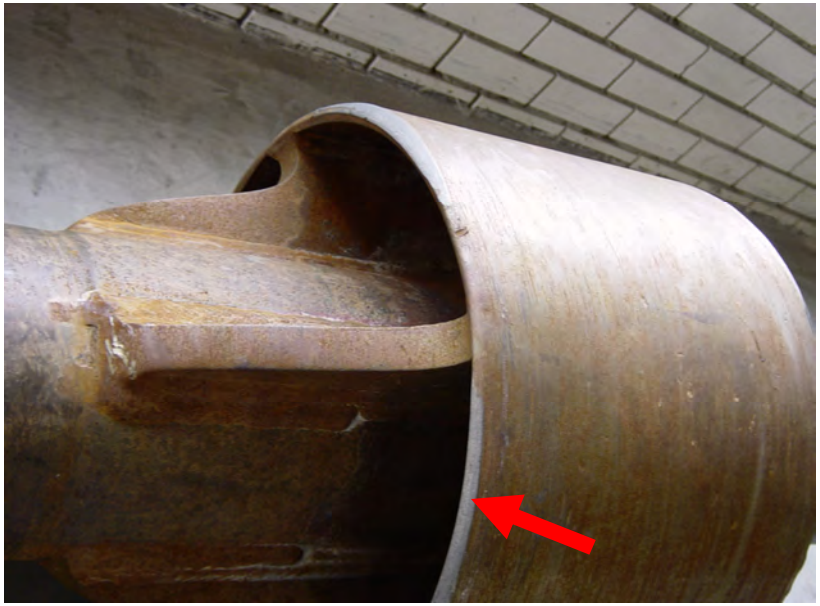
Other Wear Patterns

Other Wear Patterns

- Hole Gauging – variable diameter + abrasive conditions
- *Replacing worn tools with new tools*

PDC Bit





Questions, Comments?

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